UNIVERSITY COLLEGE LONDON
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ASSESSMENT TOOL FOR LONDON'S HEAT ISLAND

by

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Abstract

The urban environment presents distinctive features in relation to its surrounding rural areas. These include changes in ground surface, wind patterns and energy balance, which create a specific micro-climate, the urban heat island. First described by L. Howard in his book 'The climate of London' (1818), this phenomenon reduces the "cost of cold" in winter; while in summer, overheating will cause water restriction, increase in energy use and health issues. Demographic and climate change will only amplify these consequences.

This dissertation explores London's statutory framework and its agenda with regards to overheating. In practice, it is difficult to assess the value of the recently introduced National Indicator 188 and the London Plan Policy 4A.10 as there is no statutory target or framework in place, only guidance. Moreover, the current assessment tools used in London do not take into account the urban heat island effect. Only the Japanese model, CASBEE-HI, seems to provide detailed indicators and weighting systems relating to this issue.

This dissertation uses three categories of buildings as case studies: dwellings built before and after 1995 and offices built after 1995. This review highlights poor performances of the buildings studied and the limitations of the Japanese model. From these results a new assessment tool is developed, the "UHI checklist". The same case studies are assessed using the "UHI checklist" and show that this tool is able to produce meaningful results, propose adaptation strategies and assist planners implementing policies.

Contents

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List of abbreviations

BEE	Building Environmental Efficiency
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Metod
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CASBEE-HI	Comprehensive Assessment System for Building Environmental Efficiency for Heat Island relaxation
CFD	Computation Fluid Dynamics
CIBSE	Chartered Institution of Building Services Engineers
CLG	Communities and Local Government
DEFRA	Department for Environment, Food and Rural Affairs
DPD	Development Plan Documents
DTI	Department for Trade and Industry
EPBD	Energy Performance of Buildings Directive
EA	Environment Agency
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
ESDP	European Spatial Development Perspective
EST	Energy Saving Trust
FR	Floor area Ratio
GLA	Greater London Authority
HIP	Home Information Pack
HVAC	Heating, Ventilation and Air Conditioning
IBEC	Institute for Built Environment & Energy Conservation
IPCC	Intergovernmental Panel on Climate Change
JSBC	Japan Sustainable Building Consortium
LA	Local Authority
LBHF	London Borough of Hammersmith & Fulham
LCCP	London Climate Change Partnership
LEED	Leadership in Energy and Environmental Design
LGA	Local Governement Association
LSE	London School of Economics
MOL	Mayor of London
NI	National Idicator
OCG	Office of Government Commerce
ODPM	Office of the Deputy Prime Minister
PPG	Planning Policy Guidance
PPS1	Planning Policy Statement 1
RIBA	Royal Institue of British Architects
SRI	Solar Reflective Index
UCO	Use Classes Order
UHI	Urban Heat Island
UN	United Nations
UKCIP	UK Climate Impacts Programme
USGBC	U.S. Green Building Council

I Introduction

A widely used definition for Sustainable development was expressed at the World Commission on Environment and Development in 1987: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In recent years, interest towards sustainability has grown linked to the fuel crisis and compelling scientific evidences on the anthropogenic effect to global climate. This is witnessed from evidences such as the heraric blossoming pattern or more seriously the recent floods. During the summer of 2003, London experience 616 deaths who werew attributed to the heat wave (National Statistics, 2005). How can we mitigate this risk in the future?

Overheating in the capital is partly the consequence of global climate change and also a micro-climate effect, the urban heat island (UHI). The temperature increase in the urban area is related to its context: increase in anthropogenic heat source and in net radiation gains, reduction in evaporation from vegetation and in wind velocity. This study will review the recent policies, guidance and assessment tools which aim to reduce the UHI impact. It will also outline the need for a specific tool to demonstrate compliance with the National Indicator188 (CLG, 2007) and the London Plan Policy 4A.10 (MOL, 2008).

This dissertation will present the results of London building stock assessment using the Japanese model, CASBEE-HI (JSBC, 2005). This outlines a range of mitigation strategies, which will be included in a new framework. As part of the planning process, the UHI checklist could enable the construction industry to move towards reducing the impact of UHI on water restriction, energy cost and health issues.

II. London's heat island

2.1 Urban heat island (UHI)

2.1.1 Definition

A useful definition of the heat island is "thermal gradient differences between developed and undeveloped areas" (LEED NC 2.2).

Air temperature in a dense urban areas is significantly higher than its rural surroundings (Fig 2.01). This phenomenon described as the heat island was first studied by Luke Howard (1772-1864) in The Climate of London (1820). It is the most obvious climatic manifestation of urbanisation. (Santamouris, 2001) As cities grow, they impact local and regional climates.

This temperature change affects the built environment in many ways, influencing the health and comfort of its occupants, energy use, air quality & visibility levels, water availability & quality and the overall quality of life. Therefore new builds and refurbishment works should take this micro-climatic factor into account when choosing a location, designing, building and maintaining a site to reduce its loads and possibly minimise the UHI effects.

As shown in figure 2.01, the temperature profile varies across a city depending on the nature of the land cover: parks and also lakes have a cooling effect. This suggests that water features, gardens, green roofs and walls are part of the mitigation strategies. The solar energy is stored in the urban fabric during the day and released at night when the urban heat island intensity is the highest (Fig 2.02). This phenomenon is also more intense in summer; the highest value of UHI intensity was recorded during August 2003 heatwave when it reached 9°C (MOL, 2006).

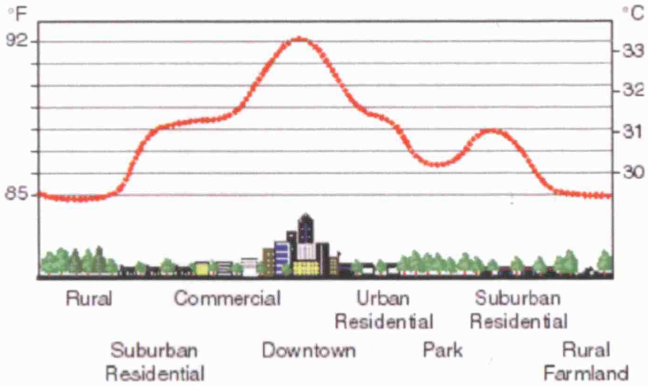


Fig 2.01 Sketch of an UHI profile, late afternoon temperature (MOL, 2006)

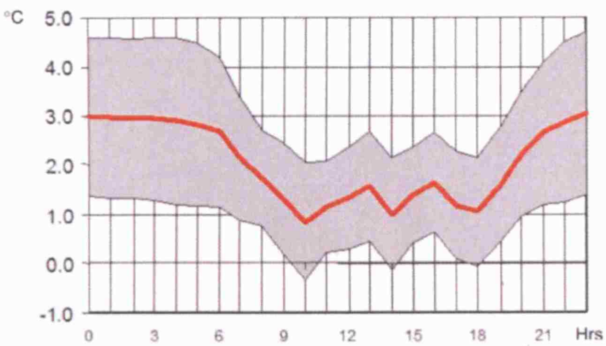


Fig 2.02 Variation in the UHI intensity for London over 24 hours for summer 2000. The solid red line indicates the average UHI intensity by hour while the shaded area shows the range of UHI intensity values for 68 percent of the observations (MOL, 2006)

Climate modification such as the UHI is caused by a number of factors, the main one being 'changes to the form and composition of the land surface and atmosphere' (MOL, 2006). Urban construction materials have different properties to the surrounding rural areas:

- thermal conductivity decreases as buildings and roads cool at a much slower rate than rural area.
- greater heat capacity; during day time solar energy is stored in the urban fabric which is then released at night.

The specific heat capacity (c) of a material 'is the quantity of heat energy required to raise the temperature of 1kg of that material by 1 degree Kelvin or 1°C' (McMullan, 2002); for example:

$c_{\text{concrete \& brickwork}}$ 3300 J/kg K > c_{wood} 1700 J/kg K

- net radiation gain increase (reflective & emissive); which is defined by the transfer of heat energy through electromagnetic waves in infra-red range (McMullan, 2002).

The warmer the temperatures are the lower the Albedo of the surrounded surfaces (Fig 2.03). The energy is stored in the upper layers of the absorbing material and later released when the external temperature decreases often at night. The Albedo or reflectivity (R) is defined by:

R = Ir / Is Ir: light reflected from a material; Is: light energy store in the material

- reduction in evaporation from soil and vegetation as urban area are much drier. The combination of impermeable surfaces and efficient drainage systems remove rain water quickly; which does not allow natural cooling processes such as evaporative cooling or evapo-transpiration by the plants.

The warmer the air temperature remains the higher bowen ratio (Fig 2.04); and less moisture is available at the surface. The bowen ratio (B) is defined by:

B = Qh / Qe Qh: sensible heat; Qe: latent heat

London's geography and morphology have a great influence on the UHI. The building activity, typology (age, size & construction), density and orientation create different patterns of anthropogenic heat; such as the demand for heating or cooling, lighting and other activities. Transport is also a significant extra source of heat and air pollution intensifying the UHI by producing local greenhouse effect. (MOL, 2006)

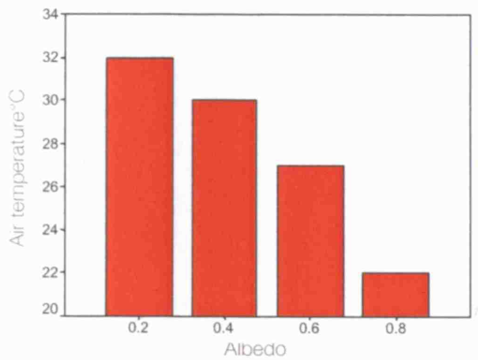


Fig 2.03 Theoretical changes in air temperature for a range of albedo at 12am on the 3rd day of a fine weather spell (MOL, 2006)

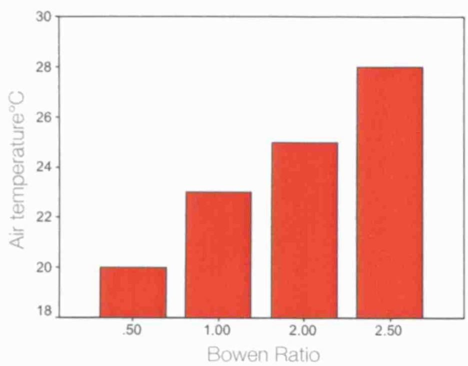


Fig 2.04 Theoretical changes in air temperature for a range of moisture conditions at 12am on the 3rd day of a spell of fine weather (MOL, 2006)

2.1.2 Evidence of heat island in London

In his book, the Climate of London (1965), Chandler showed an increase of 4°C above the rural surroundings on calm summer's days. A more recent study by Gaves & all. (2001) measured the hourly air temperature for 80 locations arranged on a radial grid across London. The epicentre chosen was the British Museum, although the location of the warmest place in the city moves in line with the wind direction (CIBSE, 2006). The pattern of the air temperature between rural reference stations and urban sites shows a clear evidence of London's UHI (Fig 2.05 & 2.06).

There is also an association between UHI intensity; surface temperature and the type of land cover (Fig 2.07 & 2.08). The low temperatures recorded in Richmond Park, 13°C, contrast with the dense urban centre where the average surface temperature is 18°C. The composition of the land cover has a direct influence on the local climate (greater heat capacity, reduced radiative cooling and reduced air speed). The anthropogenic activities intensifies this phenomenon by releasing heat into the atmosphere, it is generated by activities such as transport, heating and cooling and industrial process. This dominates the energy balance in the winter (Hamilton, 2007). A further contributor is the air pollution which creates a local greenhouse effect. This is amplified when the wind speed is low as the heat and the pollutions remain in London (MOL, 2006).

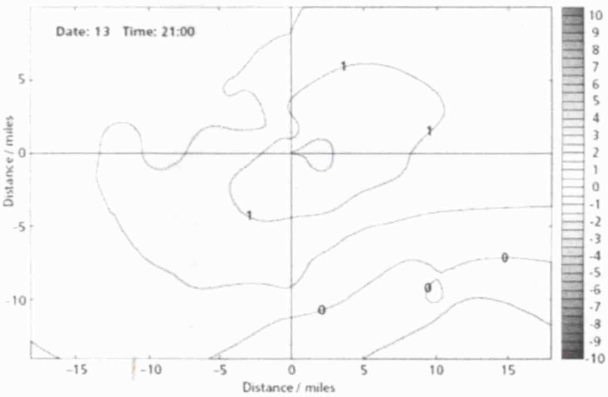


Fig 2.05 Heat island intensity distribution on a windy night; London, 13 August 1999. (CIBSE, 2006, 2-29)

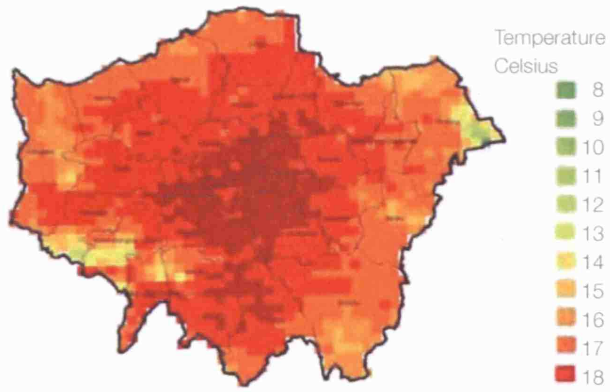


Fig 2.07 Surface temperature distribution in London for 1km2 grid at 9.30pm on the 7 August 2003. (MOL, 2006)

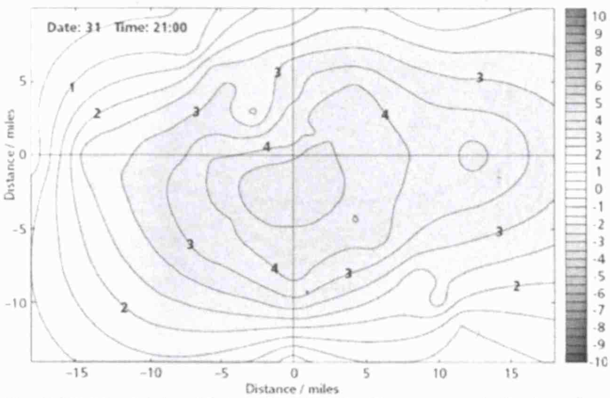


Fig 2.06 Heat island intensity distribution on a relatively calm night; London, 31 August 1999. (CIBSE, 2006, 2-29)

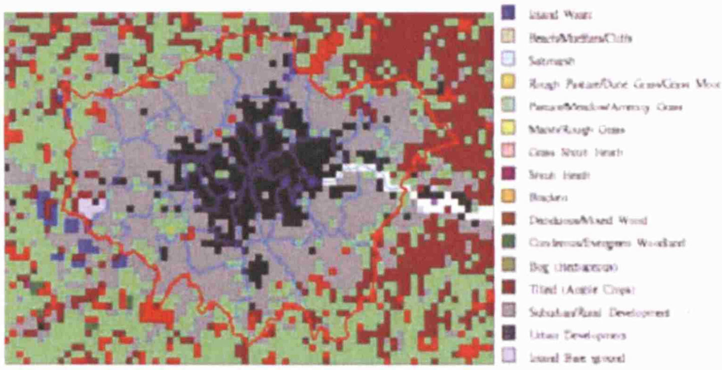


Fig 2.08 Land cover distribution across London (MOL, 2006)

2.1.3 Climate change *www.ukcip.org.uk*

According to the UK Climate Impacts Programme (UKCIP), the temperature might rise across the UK by 2 to 4.5°C by 2080 depending on the emission rate, scenario 02. In general the Southeast and London in particular will experience hotter summers (+6°C) and mild winters (+3°C) under the high emissions scenario (Fig 2.09 & 2.10). These projected changes do not take into account London's morphology and assumes a rural land-use. Moreover climate models present some uncertainty in there assumptions, such as global fossil fuel consumption, economics and population growth. Therefore there are different levels of confidence in the climate variables projected changes: high confidence for temperature & precipitation and low confidence for the wind speed and cloud cover. In summary this will only increase the effects of the UHI.

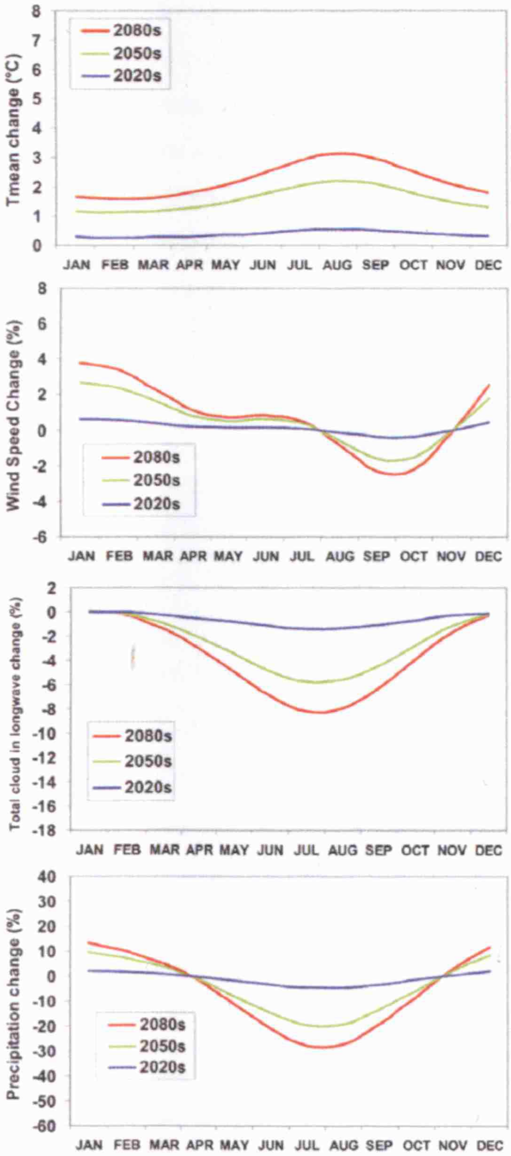


Fig 2.09 Projected changes in key climate variables for London with UKCIP02 low emissions scenario (MOL, 2006)

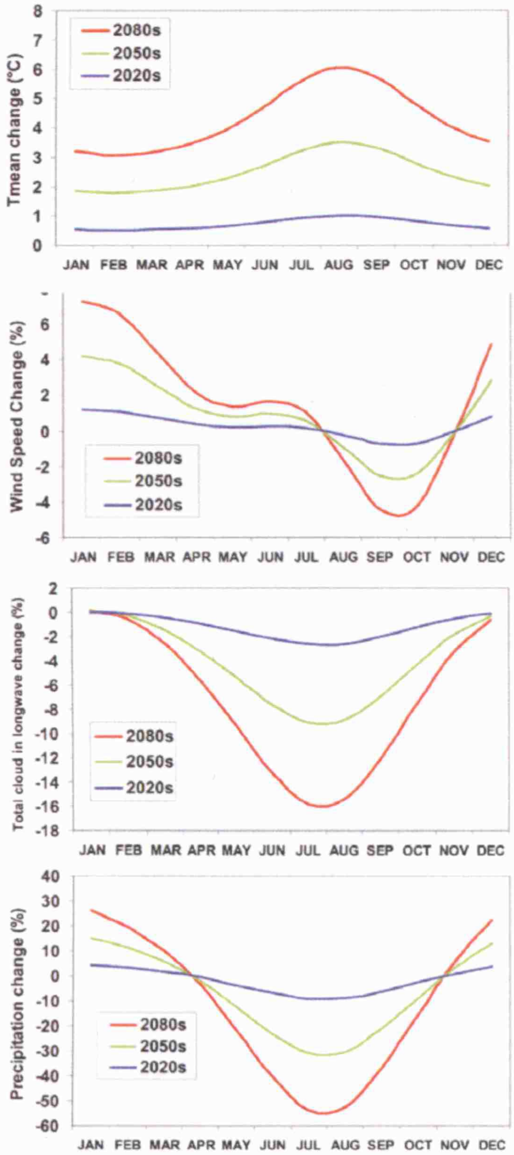


Fig 2.10 Projected changes in key climate variables for London with UKCIP02 high emissions scenario (MOL, 2006)

2.2 London's changing context

2.2.1 Geography and built form

"Each house, factory, railway station, wall and pavement creates its own distinctive microclimatic envelope and these in combination produce a substantial climatic unit, the urban climate." (Chandler, 1965. p20) The climate of a city is influenced by several variables such as the general climate of the region, the morphology of the site and its urban development.

In the South East of England, London features a temperate marine climate with regular and light precipitation throughout the year. Located at 51° 30' 35" N Latitude and 0° 06' 37" W Longitude, the temperature varies between 30.3 and 1.4°C (see table below). In the centre, near the British Museum, the temperatures could rise up to 9°C to the night as experienced during 2003 heat wave (Refer to chapter 2.1).

The prevailing wind is orientated South-West with constant wind speeds between 10 and 30km/h (Fig 2.13). Urban settlements such as London have different surfaces and atmospheric properties than its surrounding rural areas; and thereby different solar and hydrologic balance. Moreover air flow from the countryside encounters new and very different set of boundary conditions in the city. (Oke, 1987, p272) The reduction in wind speed in the urban canopy layer decreases the convection heat loss and thereby amplifies heat island effect. Its climate is dominated by the characteristics of its immediate surroundings.

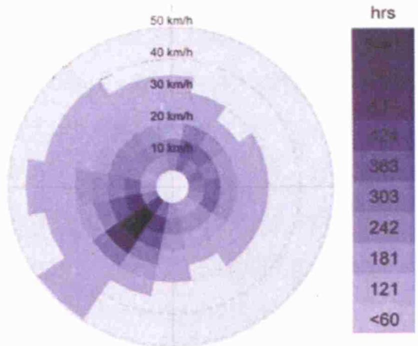


Fig 2.13 Frequency of wind speed over London (weather tool, www.squ1.com)

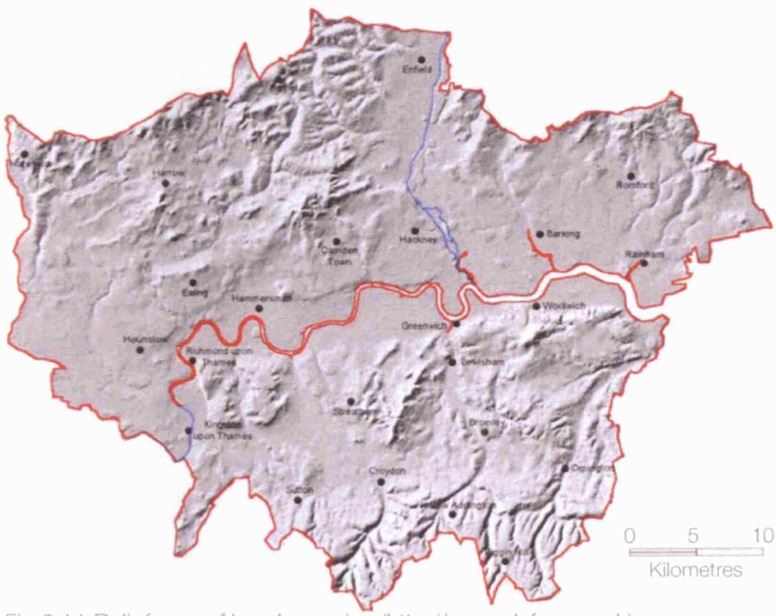


Fig 2.11 Relief map of London region (http://www.defra.gov.uk)

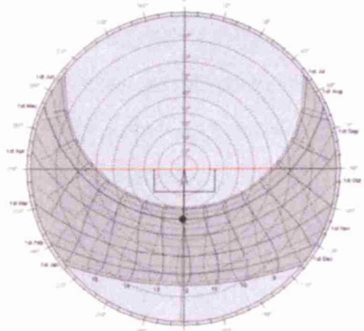


Fig 2.14 Sun path over London (weather tool, www.squ1.com)

Fig 2.12 Temperature in London (weather tool, www.squ1.com)

(in °C)	Maximum	Minimum	Average	ΔT Day / Night
Summer	23.5 – 30.3	6.2 – 10.3	15.8 – 19.7	> 10
Winter	9.7 – 13.1	1.4 – -2.2	3.4 – 6.7	
Mid-Season	17.1 – 20.7	3.5 – 7.5	8.0 – 11.2	

Looking at London psychometric chart, only 15% of occupied time is within the comfort zone (Appendix 1). By applying passive techniques such as natural ventilation or exposed mass with night-purging, then 30% of occupied time is within the comfort zone. Therefore Heating, Ventillation and Air Conditionning systems (HVAC) are required to provide comfortable space to work and live in London. Unfortunately this generates heat, a direct cause of the UHI effect.

Much of London is situated in the River Thames floodplain which crosses the city from the South-West to the East (Fig 2.11). Its low point, Heathrow Airport is only at 25m above sea level. Once this marshland was flooded by high tide and its shores reached five times their present width (Jones & Woodward, 2000). The aluvional land, underlain of clay and overlain of gravel & sand, has been extensively embanked during the Victorian time and many of the Thames tributaries now flow underground. The surrounding chalk hills average 120m above sea level (Notting Hill, Parliament Hill, Forest Hills, Primrose Hill, etc). These presented no significant obstacle to the growth of the city. (Sources: Wikipedia & Defra)
From its origins as a Roman port on the north side of the river, London has expanded steadily in circular pattern (Appendix 2). Unlike Haussman in Paris or Cerda in Barcelona, London has resisted systematic reconstruction. Its structure is loose and its fabric mainly residential: low density, with large areas of parks, open spaces and brownfield land (Appendix 2). After the Great Fire in1666, street alignment as brick terraced housing was imposed and followed since. This model consist of 2 to 3 storeys dwellings generally with a basement to house the coal store and a rectangular back garden. The typical dimensions for a plot are 6 x 30m (Fig 2.16).

The majority of dwelling stock was built before 1944, with only 4% after 1995 (Fig 2.15). This defines the main construction types in London and suggests the adaptation measures to consider in order to mitigate the UHI effect. For example most of the external wall constructions will be a cavity wall with the following layers: brick rain screen, void, brick and internal render. For dwellings built after the 1950's the internal leaf will be replace by blockwork. This construction type could easily accommodate retrofitted insulation as an internal or external layer or a cavity fill. In England and Wales the annual gain from new housing equates to 0.65% of the total stock; and the losses attributable to demolition 0.10%. This slow process allows us to make some assumptions with regards to London's built form. With regards to non-domestic buildings the ratio of demolitions to new-build floor area is 29%, with 1.1% net increase between 2004 and 2006; again a slow process (CLG, 2007).

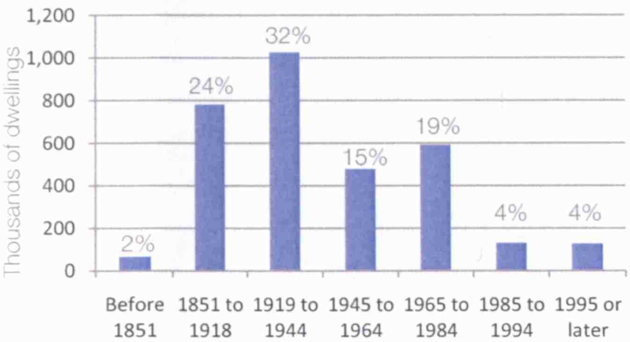


Fig 2.15 London dwelling stock by year built
(Table 110, www.communities.gov.uk/housing)

Fig 2.16 Map of Brook Green, W6.
(www.lbhf.gov.uk)

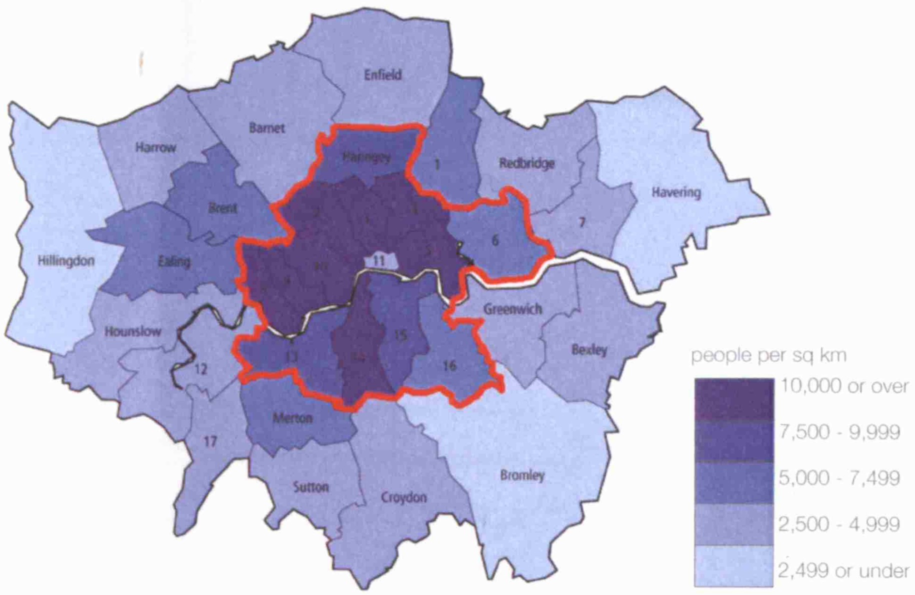
2.2.2 Demography

2.2.2.1 Population and economic growth

Population is one of the key factors when analysing development. From 29% of the global population living in urban areas in 1950; it reached 49% in 2005 according World Urbanization Prospects and is expected to grow up to 60% in 2030. (UN, 2006) The pressure we are putting on the planet and the anthropogenic effects of our activities result in the global climate change witnessed today.

In this context the London Plan 2008 foresees changes 'in scale and nature of London's population over the next 20 years' with high demand for new homes, workplace and leisure infrastructure such as hotels. Looking at the population growth over the last century London used to be the third largest city in the world from 1950 to 1960 with an average of 8.3 million habitants. Driven by decentralisation policies, London fell down to 25th place in 2005 with 8.5 million while the largest city Tokyo reached 35.2million (UN, 2006). The distribution of dwellings across London has a distinctive pattern: the centre is enclosed by a high density ring, stretching out to the north (Fig 2.17). Then density "hot spots" highlight the urban villages and town centres; like Wimbledon or Uxbridge. London sustains a diverse range of lifestyles with communities of highly differentiated income, age and ethnic distribution (LSE, 2004).

The economic growth is linked to a shift in industry: over the past 20 years, 546,000 jobs have been gained in the financial sector and service industry while 292,000 have been lost in the manufacturing sector. Tourism, hotels, restaurants and retail have also grown. Overall 90% of all employments are in the services sector and only 5% in the manufacturing industry (London Plan, 2008). These changes have spatial implications, such as the creation of large open brown field sites where warehouses once sat and lower densities in the centre where dwellings are converted into offices or shops.



1 Waltham Forest
2 Camden
3 Islington
4 Hackney
5 Tower Hamlets
6 Newham
7 Barking and Dagenham
8 Hammersmith and Fulham
9 Kensington and Chelsea
10 Westminster
11 City of London
12 Richmond upon Thames
13 Wandsworth
14 Lambeth
15 Southwark
16 Lewisham
17 Kingston upon Thames

Fig 2.17 Population density of Inner and Outer London: by London borough, 2006 (http://www.statistics.gov.uk)

2.2.2.2 Ageing population

London's population is aging as a result of an increase in life expectancy (Fig 2.21).This effect is partly balanced by the out-migration of persons at retirement age. In the recent years the lower (0 to 29) and older (65 to 85+) segments have slightly decreased; while the middle-age segment (30 to 64) has increased. This coincides with the growth of the median age of population (Appendix 3). The impact of migration is changing London's age structure; students and first time employees are moving to the centre while young families and retired couples are likely to choose a suburban home.

As the population ages, a larger proportion will be affected by heat waves. During the summer 2003, London witnessed an increase of more than 40% in its death count, with 616 deaths attributed to the heat wave (Fig 2.18). Older citizens were the most affected. The UHI amplifies the extreme hot weather events, which can cause heat related illness such as loss of concentration, sleep disorder, heat rash, dehydration, heat syncope, heat cramps, heat exhaustion and even heat stroke; especially in vulnerable populations such as the elderly (Sakabe, 2006). This phenomenon was directly linked to the increase in the global mean temperature.

The national statistic reports that "London experienced a maximum temperature of 37.9°C (100.2°F) on 10 August" (2005). In light of this event which will happen more frequently due to climate change, it becomes crucial to address the effect of urban heat island for the wellbeing of Londoners.

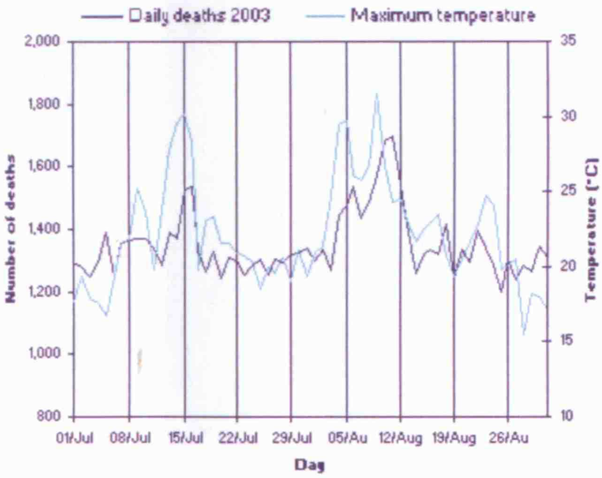


Fig 2.18 Daily deaths in England & Wales and maximum Central England temperature, July & August 2003 (National Statistics, 2005)

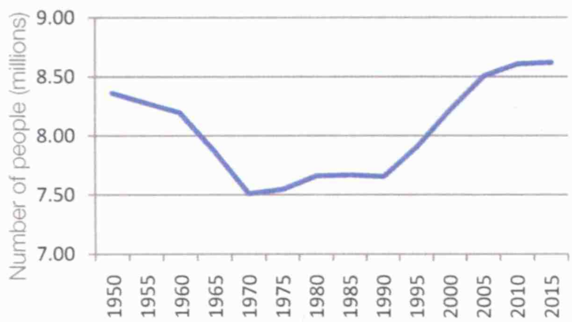


Fig 2.19 Population estimates & projections for London. (UN 2006)

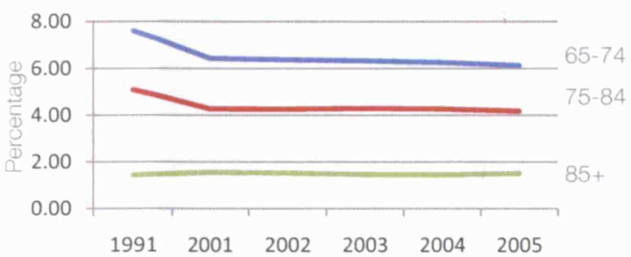


Fig 2.20 Percentage of elderly for London. (GLA 2006)

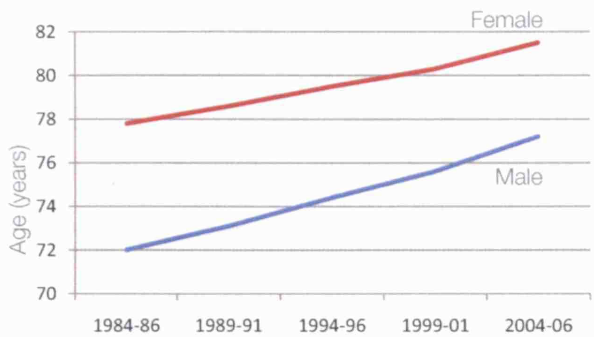


Fig 2.21 Expectation of life at birth by gender for England. (National Statistics, 2007)

SPECIAL NOTE

THIS ITEM IS BOUND IN SUCH A MANNER AND WHILE EVERY EFFORT HAS BEEN MADE TO REPRODUCE THE CENTRES, FORCE WOULD RESULT IN DAMAGE

2.2.3 Lifestyle changes: changing households

When London's population reached its peak in 1939, people lived in fewer but much larger households. Over the past 30 years we can observe a slight increase; yet growing population contained within the same footprint implies higher densities. Between 2001 and 2031 the number of households in Greater London is projected to rise by 27.48 % while the average size of households decreases by 9 % (Appendix 3).

One factor is the growth in single person households. London's population is not only growing; it is changing with implications for the future form of the city and the design of its housing stock (Fig 2.25). The average household size is shrinking (Fig 2.24), this trend encouraged the housing boom in London, which put strength on infrastructure, natural resources and biodiversity (Rogers, 2000, p2/37). This population growth has also a direct effect on the UHI intensity (Fig 2.23). With 700,000 new households to be built by 2016 how will these developments affect London Heat Island? (London Plan, 2008)

New trends should also be mention the such as different live/work patterns with mixed environment or 'working from home' scheme. The commuting journeys tend to be reduced, with less pressure on infrastructure and transport. Another trend is illustrated by the way businesses operate; the new corporate responsibility and stake holding schemes are based on integration, diversity and environmental concerns.

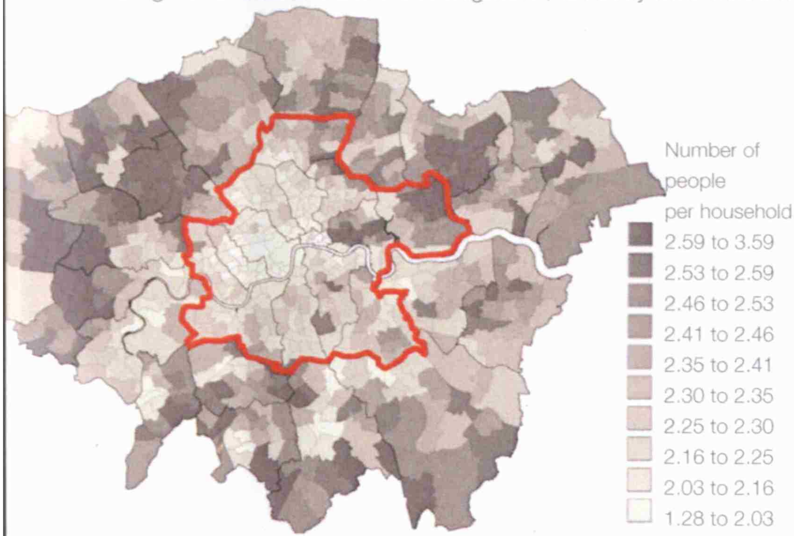


Fig 2.22 Household size (LSE 2004 based on Census 2001)

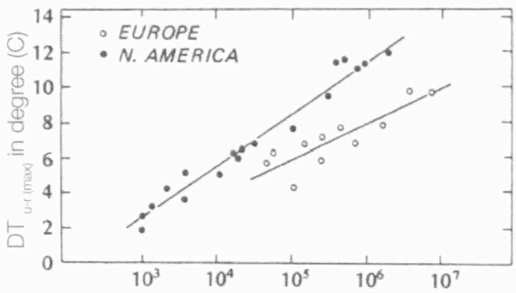


Fig 2.23 Relation between maximum observed heat island intensity ($DT_{u\text{-}r(max)}$) and population P for North American and European settlements (Oke, 1987)

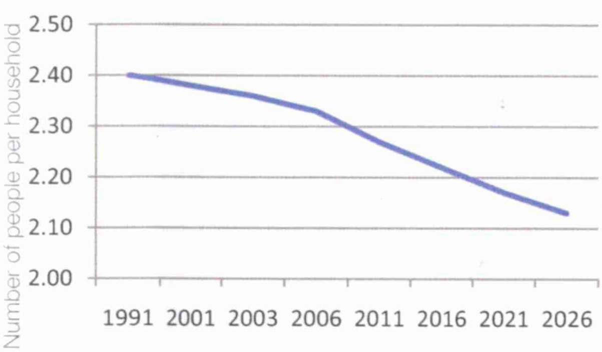


Fig 2.24 Household size estimates & projections for London. (GLA 2006)

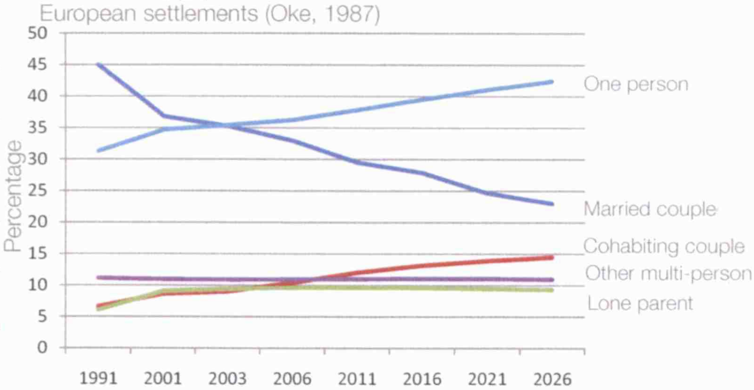


Fig 2.25 Household type estimates & projections for London. (GLA 2006)

2.3 Summary

This chapter has attempted to provide a physical context which highlights the cause and consequences of London's heat island. With growing concerns related to climate change and demographics, existing and future developments will need to adapt to extreme temperatures.
To summarise the issues, we should focus on the following five main factors in the development of an assessment tools (Graves & all. 2001):

- urban form and wind flow;
- composition of the land surface: thermal and radiative properties;
- dry land: landscaping, vegetation and water features;
- heat produced by human activities (transport, industrial processes and air conditioning);
- air pollution, local greenhouse effect.

As reviewed in chapter 2.2.2.2, the effect of heat on mortality in London appears when daily mean temperature reaches 25°C. The effects of the 2003 heat wave were greatest amongst the elderly. However the UHI can be beneficial in winter months as it reduces the 'cost of cold' (Keatinge & Donaldson, 2000). Good design and effective mitigation strategies can fulfil both seasons by:

- reducing infiltration rate;
- reducing heat loss through building fabric;
- using deciduous planting which provide solar shading in summer only.

One further element needs to be explored and that is the statutory framework. In which decision-making process the UHI assessment tool will apply? The following chapter will review the built environment current policies, rules and regulations and their recommendation toward UHI and specifically overheating.

III. London's statutory framework

A review of the current policies, rules and regulations will reveal in which decision-making process the new assessment tool should apply. This chapter is based on Speaight & Stone handbook (2001).

3.1 Statutory authorities

3.1.1 Local authorities

In 1985 the Local Government Act abolished the Greater London Council and redistributed its functions between the 32 London boroughs, the City of London and specialized representatives (fire services & districts highways). Subsequently the Greater London Authority (GLA) was established in 2000, which provides global strategic planning on economic and social development and environmental improvement. It is composed of a directly elected Mayor and a separately elected Assembly. Overlooking this structure, the Secretary of State has supervisory powers and may overrule planning decisions.

3.1.1.1 Greater London Authority (GLA)

The Local Authority (LA) is governed by a council elected every four years. It is a legal person, capable of suing and being sued in court. A directly elected Mayor and a separately elected Assembly form the executive power. Its officers give advice and carry out instructions, while the council decides all matters of policy by committee and council meetings (Speaight & Stone, 2001).
The London Plan sets out policy framework and guidance on the Mayor's 'Spatial Development Strategy' looking forward 15 to 20 years. It is subject to an ongoing monitoring process and revised annually, which takes into account the following themes (MOL, 2008, vii):

- social: Londoners' health;
- economic: equality of opportunities;
- environmental: sustainable development.

It includes funding and implementation strategies but also land use and future development, which impacts on infrastructure, especially transport. The London Plan also takes into account the European Spatial Development Perspective (ESDP) and other European directives.
With regards to London's growth the guidance are to (MOL, 2008, p3):

- create a compact city: higher densities & plot ratios by using brownfield sites;
- be energy and waste efficient;
- improve accessibility and integrate with the public transport system.

One of the Mayor's objectives is 'to make London an exemplary world city in mitigating and adapting to climate change and a more attractive, well-designed and green city'. (MOL, 2008, p10) This sets out targets for energy use, waste treatment, noise pollution, air quality and biodiversity. It also analyses 'potential threat from summer hotspots and identifies heat sensitive land uses.' (MOL, 2008, p10) Chapter 4A looks at London's possible mitigation and adaptation strategies to climate change; in particular:

- Policy 4A.9 Adaptation to Climate Change

" The Mayor will, and other agencies should, promote and support the most effective adaptation to climate change, including:

. ***minimising overheating and contribution to heat island effects;***

. ***minimising solar gain in summer;***

. contributing to reducing flood risk including applying principles of sustainable urban drainage;

. minimising water use and protecting & enhancing green infrastructure."

- Policy 4A.10 Overheating

" The Mayor will, and boroughs should, strongly encourage development that avoids internal overheating and excessive heat generation and contributes to the prevention of further over-heating, especially where the urban heat island is most intense. ***Developers should demonstrate how development could be made heat resilient in design, construction and operation.*** The Mayor will work with partners to reduce the heat island effect through energy efficiency and appropriate design."

In order to implement this policy, a guidance was published by the Mayor of London in 2006; 'London's Urban Heat Island: A summary for Decision Makers'. It introduces the causes and consequences of the UHI effect and proposes some mitigation strategies, such as:
cool roof (low albedo roofing materials), green roof, planting trees & vegetation, cool pavements (low albedo & good water permeability), sky view factor (street proportion & wind flow) and heat wave detection systems. To conclude, this guidance lists six actions towards a more effective understanding and management of the UHI, of which:

- developing a network of weather stations, an urban energy balance model and a decision support tool for planners & designers;
- creating a local heat wave plan based on pathology studies & anthropogenic heat emission model;
- starting a series of tests that project and collect climatic data to assess their efficacity.

The London Climate Change Partnership (LCCP) promotes and supports adaptation strategies, such as the publication 'Your home in a changing climate' edited in February 2008. This report focuses on three consequences of climate change: flooding, water stress and overheating. It aims to reduce temperature while keeping CO_2 emissions, noise and wasted heat to a minimum.
With regards to overheating, the "costs for a typical un-adapted house (...) would be approximately £16,000, but if winter warmth measures have already been installed, the cost of adaptation package

would be halved to around £8,000." (p40) The proposed mitigation strategies are clearly presented with their benefits, their limitations and their costs implication. Case studies look at retrofit measures for a 1930s & 1960s house and a block of flats which promote passive measure. These should be planned and installed in advance, unlike air conditioning units.
Although the GLA has introduced a policy statement on overheating and published guidance; no target has been neither set nor assessment strategies.

3.1.1.2 London's 32 Boroughs and the City of London

The boroughs are responsible for development control, housing, refuse collection, clean air, drainage & public health (but not sewerage and water supply), parks & opens paces, maintenance of roads, etc. With regards to overheating strategies, planners should integrate adaptation measures into Development Plan Documents (DPDs) and other planning policy tools such as sustainability appraisal, SPDs and guidance; in accordance with the Planning Policy Statement 1 (PPS1): 'delivering sustainable development' (ODPM, 2005):
Key Principle 13 ii : "Regional planning bodies and local planning authorities should ensure that development plans contribute to global sustainability by addressing the causes and potential impacts of climate change – through policies which reduce energy use, reduce emissions (...), promote the development of renewable energy resources, and take climate change impacts into account in the location and design of development."
A supplement to this document was edited in December 2007. It specifically refers to the UHI in the urban cooling definition: "Moderating high summer temperatures, through for example the layout of urban open space and shading from trees. Climate change will exacerbate the temperature gradient that rises from the rural fringe and peaks in city centres. This is described as *'the urban heat island'* because the warmer urban air lies in a 'sea' of cooler rural air." (p7) Planning authorities should take this factor into account when selecting land for development (Article 24).
The recently introduced National Indicators for Local Authorities & Local Authority Partnerships (CLG, October 2007) also refer to 'heat waves' in the environmental sustainability section, NI 188: 'Adapting to climate change'.

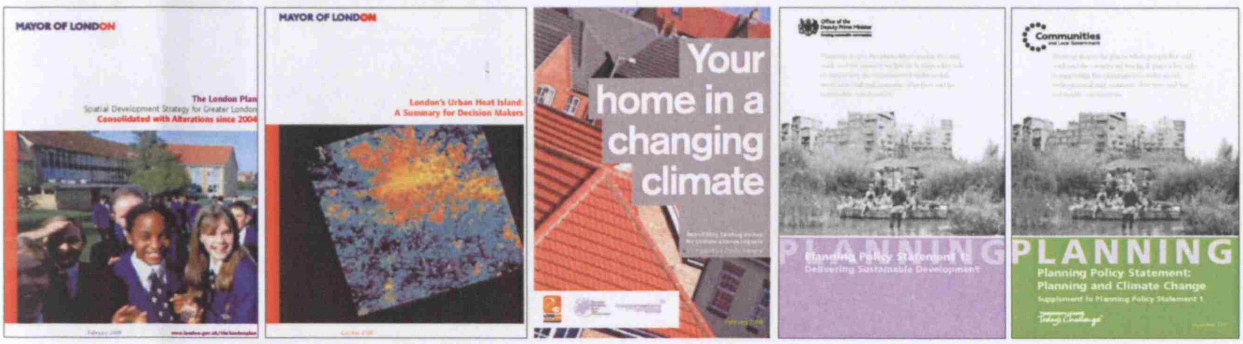


Fig 3.01 Local Authority relevant publications with regards to the UHI effect.

Again no explicit target is mentioned; but the discussion could start: How can the UHI effect be assessed to comply with these policies?
Paul Baker, Senior Environmental Policy & Projects Officer at Hammersmith & Fulham Borough Council; noted that "overheating is difficult to assess in the current planning framework. A tool with supplementary guidance should help identifying best practice strategies" (Appendix 4).

3.1.2 Other statutory bodies

As part of the planning process other bodies should be consulted:

- English Heritage established in 1983 secure ancient and historic monuments and promotes conservation areas. Developments affecting such sites should be monitored, but in most cases archaeological trenches or a watching brief will be the norm.

Through their dedicated website on climate change (www.climatechangeandyourhome.org.uk) English Heritage give some guidance on temperature and sunlight. Most traditional building forms should respond well during heat waves because of their solid construction. With regards to solar gain, blinds and shutters should be restored. In any case, work on a listed building or in a conservation area will need to be approved by the LA through planning. Some background information can be found in the publication Climate Change and the Historic Environment (2008).

- The Environmental Agency (EA) established in 1995 is responsible for pollution control, water resources, and environmental duties for sites of special interest and flood defences. It received guidance from ministers on its main strategies.

Although this agency has a clear program with regards to water stress and flooding, waste management and biodiversity; overheating is only taken into consideration for its impact on general health. (Local Government Association, 2008)

- Additional controls may be considered under specific development acts; i.e. Factories Act 1961, Offices, Shops and Railways Premises Act 1963, Clean Air Act 1993, etc.

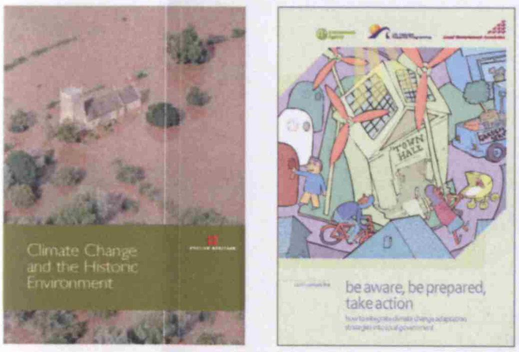


Fig 3.02 Other statutory bodies relevant publications with regards to the UHI effect.

3.2 Regulations

3.2.1 Buildings Acts & Regulations

Planning legislation generally relates to the external appearance of the development and the coordination with local amenities. The Building Act 1984 and the Regulations made under it relate to the construction and design of buildings. They contain no technical detail but are supported by a series of 14 approved documents, which give practical guidance (Appendix 5). They also refer to other non-statutory documents such as the British Standards.

These have an important role to play in the design of building; some of the guidance related to UHI mitigation strategies are listed below:

- Approved Document F: Means of ventilation (2006)

The air intakes should be placed away from direct pollution sources: urban traffic, parking areas, adjacent building exhausts or stack discharges.

- Approved Document J: Combustion appliance and fuel storage system

This document offers guidance on the position of extracts, the higher the better as reviewed in 5.2.1.3. The "flues should be high enough to ensure sufficient draught to clear the products of combustion." (2.8) "The outlet from the flue should be above the roof of the building." (2.10)

- Approved Document L: Conservation of fuel and power

For new buildings the performance of the fabric, the heating & hot water and the fixed lighting systems should at least meet set design limits; i.e.

- Fabric U values (W/m2.K): wall 0.35, floor 0.25, roof 0.25 & openings 2.2 (Table 2);
- Mechanical ventilation systems: heat recovery efficiency 66% (Table 3);
- Fixed air conditioners: energy efficiency C (paragraph 41)
- Design air permeability: 15m3/h.m2 at 50Pa (paragraph 63)

This document also offers guidance on passive control measures to limit solar gain and refers to CE129 Reducing overheating, a designer guide (EST, 2005) and CIBSE TM 36 (refer to 3.2.2).

Fig 3.03 Building regulations which should be consider to mitigate the UHI effect.

3.2.2 Guidance documents

The approved documents refer to some best practice guides, which introduce some benchmarks for overheating and some mitigation strategy with regards to the UHI effect:

- CIBSE Guide A: Environmental design (2006)

a. Overheating 1.4.2.4 Buildings should provide a comfortable environment to live or work; the benchmark for summer peak temperatures are as follow:

. offices, schools and living area in dwellings: could exceed 28°C for less than1% of the occupied time

. bedroom in dwellings: could exceed 26°C for less than 1% of the occupied time.

b. Heat island effect 2.10 This chapter evaluates the impact of the UHI on the cooling load and proposes some adjustment to Heathrow weather file.

- CIBSE TM36: Climate change and the indoor environment: impact and adaptation (2005)

After analysing the UKCIP02 scenarios, this document reviews the implication of space heating and comfort cooling. Taking into account the predicted temperature, the case studies assess in detail different building types: dwelling, offices and schools. Base on this study adaptation strategies are drawn which include passive measures and mechanical cooling.

- CE 129: Reducing overheating, a designer guide (EST, 2005)

This document highlights the factors affecting overheating: solar gain, internal gain, thermal mass and ventilation. Then it reviews practical examples to address the risk of overheating by applying either individual or combination of measures. The impact of each measure is illustrated using a bubble plots diagram (Fig 3.04).

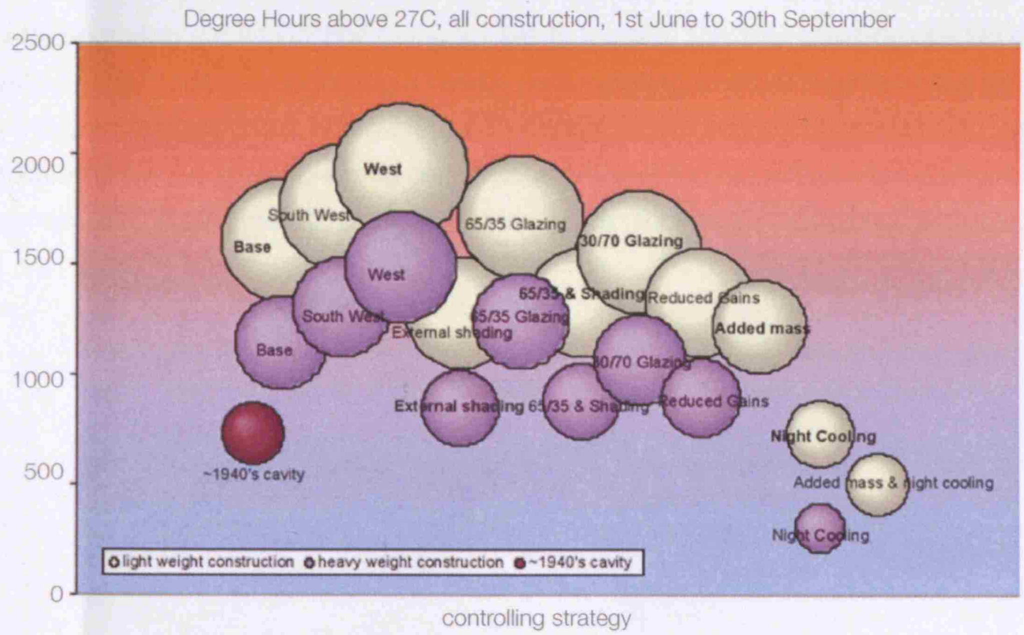


Fig 3.04 Overheating risk for different design options (EST, 2005, fig 2)

3.3 Planning law

The Town and Country Planning Act 1947 gives the borough councils control of the development of all land including buildings. As the amount of land is limited, this was introduced to reduce the pressure from developers and balance out working & living space.
The current 'Planning Acts 1990' are composed of four documents: Town and Country Planning, Listed Buildings and Conservation Areas, Hazardous Substances and Consequential Provisions. The Department of the Environment produces Planning Policy Guidance Notes (PPG) first issued in 1988.

Planning process

First 'Unitary Development Plans' are drafted by the LA, then adopted after a lengthy process involving public consultation. These are of high importance in any decision as to grant or refuse planning permission. The planning process consists of two parts:

1. production of information on the future development, including site inspection, project brief, level of planning control and planning zone;.
2. day-to-day control over the development.

Ultimately the Secretary of State decides and is accountable to the Parliament.
The planning application will be made to the local planning authority, the Borough Councils or the Common Council (for the City of London). In some cases, the developers will apply for outline planning permission. This process will allow to test a scheme potential. If granted he will then apply for full planning permission; which might be granted subject to conditions.
The Section 106 or planning obligation provides an agreement between the LA and the developer which offers planning benefit to the community as part of the grant of planning permission. For example as part of a project which granted planning permission for a supermarket, the developer will pay for upgrading a road junction giving access to the site. This tool could be used to mitigate overheating at city scale, i.e. upgrading a nearby park, creating a nature reserve on the site, etc.
Unless the permission specifies otherwise, it will only last for five years. This is to prevent an accumulation in the records of planning permissions granted and not acted. Having begun a development, the LA will issue a completion notice which requires the completion within a certain period.

3.4 Summary

If London is going to adopt the principle of sustainable development, it will need to introduce policies and commit resources to mitigate the UHI effect.

At national level, PPS1 and its supplement recommend to consider urban cooling when selecting land for development. In addition, the recently introduced National Indicators and specifically NI 188 measure the Local Authority progress on assessing and managing climate risks, including heat waves.

At local level, the London Plan includes a policy on overheating (4A.10) which requires developers to 'demonstrate how development could be made heat resilient in design, construction and operation'.

In practice, it is difficult to assess the value of these policies as there is no target or framework in place providing evidence. Is the policy working?

The guidance provides advice on mitigation strategies for existing or new built development in particular dwellings. However none introduce benchmarks or assessment tools, hence the evidence will come in many forms.

This study will attempt to establish a set of information that will address the UHI effect by analysing current assessment methods and indentifying common indicators.

IV. Aims and intent

This dissertation intents to develop a new assessment tool for London heat island. This involves an initial review of the evaluation methods currently used in London which should answer the following questions: How does the evaluation process work? On which basis? Is the UHI taken into consideration?

Evaluation and monitoring tools should be impartial and transparent to deliver comparable results and advice. The limitation of the current tools should be highlighted as it will form the basis of the analysis. Subject specific, the new UHI assessment tool should be able to take into account various context, planning and design issues. It aims to assist planners, design team and stakeholders to understand and communicate the project strength and limitation, but also to propose solutions towards sustainable development.

Once the indicators have been identified, the framework provides a method which guides the evaluation aiming at long-term sustainability. As part of the planning process, the UHI assessment intents to start at early design stages and to be finalise one year after completion. At the heart of the assessment process lies the questions: who manages? who is accountable?
In the publication 'Your home in a changing climate' (LCCP, 2008), the policy makers should: "enable (produce guidance), encourage (funding, grants and incentives), engage and exemplify (apply the measures to public buildings)". Individual, organisations and firms have also a role to play, such as:

- professional installers, fitters, suppliers and retailers;
- existing group, campaigns and programmes;
- utility, mortgage and insurance companies.

The following chapters will review the existing framework and test them with a series of case studies, in order to create a new assessment tool for London heat island.

V. Methodology

To follow the Brandon and Lombardi analysis of sustainable developments (2007), a set of shared values (indicators) need to be drafted to allow discussion to take place, then stakeholders will define the logic of the system (weighting). This process is complex as each stakeholder is part of a system which might have different interests; i.e. transport and retail system rely on each other while biological and business might have different a approach. It is likely that the assessment tool will be part of a policy at local, national or international level. It will engage the evaluation of performance against set criteria. These must have a degree of flexibility and be able to adapt with time. The tool should also facilitate the debate understood by all participants and propose some mitigation strategies. Finally, the process should contribute and relate to the wider sustainability issues: economical, social and political. The built environment framework recently established in South Africa illustrates this issue by taking into account the 'Brown' and the 'Green' agendas (Watermeyer, 2006).

This study intends to develop a new assessment tool evaluating the London heat island effect. Over the past twenty years, a number of environmental assessment systems have been introduced world wide (Fig 5.01). In this chapter, we should review the existing frameworks and specifically the indicators and weighting systems chosen to assess the urban heat island effects.

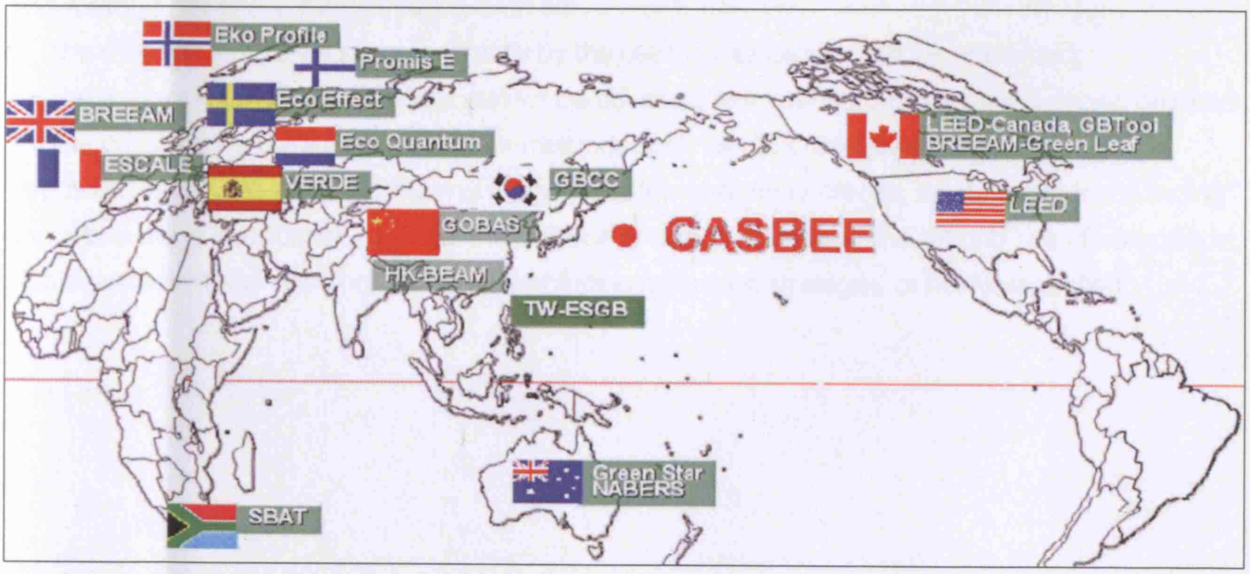


Fig 5.01 Assessment tools evaluating sustainable development worldwide (Mochida, 2006)

5.1 Current assessment tools

A number of environmental assessment systems have been introduced around the world including BREEAM & the Code for Sustainable Homes in the UK, LEED in the US and CASBEE in Japan. This study will focus on these four tools (Saunders, 2007).

5.1.1 BREEAM *www.breeam.org*

BREEAM (Building Research Establishment Environmental Assessment Method) was first launched in 1990; it assesses existing buildings and new developments from conception to completion. Reviewed annually, it was first used to assess Offices; since then other building types have been added: Retail, Industrial, Schools, Housing, Courts, Prisons and Hospitals, also a bespoke and an international version.

It is a voluntary process; however it becomes more and more a 'must-have' requested by planning authorities or clients; such as English Partnerships, OGC and Housing Corporation which has requested a minimum rating "very good" for all new scheme since 2006.

The BREEAM assessment process is carried out by a licensed assessor who produces a report outlining the building's performances against set criteria and the overall score gives the BREEAM rating. Each criteria is weighted by environmental importance; 'energy' is highest and 'water' lowest. The main 7 indicators are: Management, Health & Wellbeing, Energy & Transport, Water, Materials, Land Use & Ecology and Pollution. There are some variations between each building type versions but the majority of the ratings follow the scale:

Pass > 25%	Very good > 55%
Good > 40%	Excellent > 70%

This method has a few disadvantages such as:

- the method can not be process directly by the user; an assessor must be appointed;
- the system is fairly rigid: variables cannot be adjusted, few interaction through the design process;
- the criteria are more limited then other methods such as LEED and CASBEE.

The 2008 version will introduce minimum standards for mandatory credits, a new rating 'outstanding' and a two stage certification process: the first one at design stage and the second one at completion. This assessment tool does not mention overheating mitigation strategies or heat island effect.

5.1.2 The Code for Sustainable Homes *www.communities.gov.uk/thecode*

Introduced in April 2007 as a voluntary scheme for new build housing, this code has been developed by the Department for Communities and Local Government (CLG) using BRE EcoHomes Systems. It aims to complement EPC system (Energy Performance Certificates) introduced in April 2008 under the Energy Performance of Buildings Directive (EPBD) and part of the Home Information Pack (HIP). This requires all new homes and dwellings for sale or rent to have an Energy Performance Certificate which provides key information on its energy efficiency and carbon performance. (www.communities.gov.uk/planningandbuilding/theenvironment/energyperformance/)

The Code's main features are:

- Individual Dwelling Assessment processed by a certified assessor;
- Assessment in 2 stages – design stage and beyond completion;
- Fixed Minimum Standards for some categories and points allocated for "Lifetime Homes";

The 9 design categories associated flexibility are summarised in the following table:

Categories	Weightings (%)	Flexibility
Energy & CO2	36.4	Minimum standards at each level of the Code
Potable Water	9	
Surface Water Runoff	2.2	Minimum standard at Code entry level
Materials	7.2	
Waste	6.4	
Pollution	2.8	No minimum standards
Health and Wellbeing	14	
Management	10	
Ecology	12	

Fig 5.02 Flexibility of the Code (CLG, 2006)

- Energy based on percentage improvement over Building Regulations (see below).

Once the scheme is assessed, the points are added and the total score given, following 6 levels:

Level 1 - 36 pts   Level 3 - 57 pts   Level 5 - 84 pts
Level 2 - 48 pts   Level 4 - 68 pts   Level 6 - 90 pts

The minimum requirements for energy and water are as follow:

Code level	1	2	3	4	5	6
Energy (% improvement > TER)	10%	18%	25%	44%	100%	Zero Carbon
Water (litres / person per day)	120	120	105	105	80	80

Fig 5.03 Requirements of Code Levels (CLG, 2006)

By the end of 2008 the assessment will be mandatory with level 4 as minimum standard at the end of 2013 and level 6 for 2016. Unfortunately this assessment tool does not mention overheating and credits related to transport and amenities are omitted.

5.1.3 LEED www.usgbc.org

LEED was launched in 1998 by US Green Building Council (USGBC). It has eight versions; the most commonly used are LEED NC for new commercial construction and major renovation projects and LEED Homes.

The LEED assessment process is carried out by the project team although an accredited professional (LEED AP) could assist in compiling the documentation required and then submit it to the USGBC. The NC version is used throughout the design and construction phase, while the certificate is issued after completion.

There is no weighting system; instead each credit is worth one point; which makes it easy to calculate and address each issue. There are 4 final ratings available (points of LEED NC version 2.2):

Certified	26-32 pts	Gold	39-51 pts
Silver	33-38 pts	Platinum	52-69 pts

The six main criteria are as follows: Sustainable Sites (14pts), Water Efficiency (5pts), Energy & Atmosphere (17pts), Materials & Resources (13pts), Indoor Environmental Quality (15pts) and Innovation & Design Process (5pts).

As part of Sustainable Sites (SS), mitigation strategies to reduce Heat Island effect are included under:

- SS credit 7.1 (non-roof)

OP 1: 50% of the site hard landscape in the shade or covered with paving materials of SRI > 29 or open grid pavement system;

OP 2: minimum 50% of the parking spaces should be under cover.

- SS credit 7.2 (roof)

OP 1: minimum 75% of the roof surface covered with roofing material of SRI > 78 (low-sloped roof < 2:12) and SRI > 29 (steep-sloped roof > 2:12);

OP 2: minimum 50% of the roof surface covered with green-roof

OP 3: install high albedo and green roof as a combination of OP 1 & OP 2, with

(area of SRI roof / 0.75) + (area green roof / 0.5) = roof area

with SRI: Solar Reflectance Index, surface's ability to reflect solar heat, define as standard black is 0 (reflectance 0.05 & emittance 0.9) and standard white is 100 (reflectance 0.8 & emittance 0.9).

These two indicators intend to 'minimize the impact on microclimate, human and wildlife habitat'. Although LEED includes some UHI mitigation strategies, it does not take into account the wind effect and the anthropogenic heat release.

The 2008 version should include geographic & climatic site constraints and give more importance to material, ventilation and indoor air quality.

5.1.4 CASBEE *www.ibec.or.jp/CASBEE/english/overviewE*

The first version of CASBEE was developed in 2004 by the Japan Sustainable Building Consortium (JSBC) which includes academic, industrial and governmental partners. CASBEE stands for Comprehensive Assessment System for Building Environmental Efficiency. Divided between residential and non-residential building types; it can be used throughout the life of the project. In some districts, this compulsory tool is part of the local regulatory directive; it has 4 different versions, including:

- Tool-0: Pre-design (CASBEE-PD) : project's environmental impact, planning & site selection.
- Tool-1: New Construction (CASBEE-NC): from conception to design and construction; this optimizes the building performance.
- Tool-2: Existing Building (CASBEE-EB): for buildings which have been occupied for at least a year.
- Tool-3: Renovation (CASBEE-RN) generates building upgrades proposals & assess improvements.

Althrough CASBEE's basic tools can assess apartment blocks, it is not best suited for small detached houses which could be assess using CASBEE for Home (DH). CASBEE includes four specific tools:

1. CASBEE-1TC: Temporary Construction
2. CASBEE-HI: Heat Island
3. CASBEE-UD: District & Region
4. CASBEE-DH: Detached House

Unlike BREEAM, this self assessment system is based on the Canadian model GBTool (Appendix 6). Weighting each criteria with a scale of 1 to 5; the average sum is balanced against the surrounding conditions and the floor area ratio. The final score BEE (Building Environmental Efficiency) balances the Quality & Performance credits (Q) and the Load reduction credits (L) [BEE=Q/L]; it is rated against five categories: S: excellent $BEE_{HI} > 3.0$

A: very good $2.99 > BEE_{HI} > 1.5$

B+: good $1.49 > BEE_{HI} > 1.0$

B-: rather poor $0.99 > BEE_{HI} > 0.5$

C: poor $0.49 > BEE_{HI}$

The six main criteria are (Appendix 6)

- Quality of building performance (Q)

Q1: Indoor environment (noise & acoustics, thermal comfort, lighting & illumination, air quality);

Q2: Quality of service (service ability, durability, flexibility & adaptability);

Q3: Outdoor environment on site (eco-system, town & landscape, culture & regional character)

- Building environmental Load (L)

L1: Energy (natural energy, efficiency in building system, efficient operation);

L2: Resource and material (water resource, eco-materials);

L3: Off-site environment (air pollution, noise & offensive odours, wind damage, lighting damage, heat island effect, load on local infrastructure).

Some of CASBEE limitations are that it does not consider the financial (capital and running cost), aesthetical or social aspects. Location specific, it includes elements of the Japanese building standard; such as earthquake resistant structure (Q2 2.1.1). On the other hand this tool is very thorough; 44 CASBEE credits do not have an equivalent in BREEAM including the Heat Island effect mitigation strategies included in Q3.3.2 (Improvement of the Thermal Environment on Site) and L3.6 (Heat island effect).

5.1.5 Comparison Summary

The precedent review summaries the approach used by BREEAM, the Code for Sustainable Homes, LEED and finally CASBEE. A comparison of the environmental standards demanded to mitigate the Urban Heat Island effects is drafted in the following table:

	BREEAM	**Code for Sustainable Homes**	**LEED**	**CASBEE**
Launch date	1990	2007	1998	2004
Rating	4 levels pass, good, very good & excellent	6 levels	4 levels certified, silver, gold & platinum	5 levels C, B-, B+, A & S
Information gathering	Design team or assessor	Design team or assessor	Design team or accredited professional	Design team or assessor
Assessment	Assessor	Assessor	USGBC	Design team
Updated process	Annual	As required	As required	As required
Governance	BRE	CLG	USGBC	JSBC
Heat Island effect	No review	No review	SS 7.1 Ground surface covering materials SS 7.2 Roof covering materials	Q3.3.2 Improvement of the Thermal Environment on Site L3.6 Heat island effect
Heat Island specific tool	N/A	N/A	N/A	CASBEE-HI
Availability of information	www.breeam.org	www.communities.gov.uk/thecode	www.usgbc.org	www.ibec.or.jp

Fig 5.04 Comparison summary table (Governance & Saunders, 2008)

From this review we can conclude that CASBEE and in particular CASBEE-HI is the only model available to assess the Urban Heat Island effects. In the following chapter we will review this tool in detail.

5.2 CASBEE-HI *www.ibec.or.jp/CASBEE/cas_hi*

Developed as an additional tool to the main CASBEE method, CASBEE-HI (tool-4) focuses on the Urban Heat Island effect. It stands for Comprehensive Assessment System for Building Environmental Efficiency for Heat-Island relaxation.
UHI occurs at the city scale, but the mitigation strategies relate to the building and human scale as various consequences occur near or as a result of building design. In fact individual buildings could have a significant impact on the surrounding microclimate.
This tool was introduced in Japan in August 2005 to follow an announcement by the Japanese Government Committee in March 2004 and the building design guidelines issued by the Ministry of Land, Infrastructure and Transport the following July. It is based around the following concept: 'urban climate is the combination of microclimate around each individual building' (Mochida, 2006).

As per CASBEE assessment process, all the issues are split into two categories : quality measures Q and load reduction L; although only five items are reviewed: Urban Ventilation (Q1 & L1), Shading (Q2 & L2), Ground surface covering materials (Q3 & L3), Building materials (Q4 & L4) and Anthropogenic heat from building equipments (Q5 & L5). (Appendix 7)
Set within the planning envelope (CV), these sub-issued weighted from a scale of 1 (un-sustainable) to 5 (very sustainable). Then the average sum is multiplied by a coefficient dependant on the surrounding conditions and the floor area ratio.
Once this assessment has been carried out the main indicator BEE_{HI} is calculated using the following equation:

$$BEE_{HI} = Q_{HI} / L_{HI}$$

with Q_{HI}: Quality of Building Performance, optimization of comfort in pedestrian spaces;
and L_{HI}: Building Environmental Load, minimization of environmental load on adjacent areas.

or

$$BEE_{HI} = [25 \times (S_{QHI} - 1)] / [25 \times (5 - S_{LHI})]$$

with S_{QHI}: total score of Q category and S_{LHI}: total score of L category

The higher the BEE_{HI} scores the greater the effect of mitigation measure; BEE_{HI} is rated across the same 5 ranks than CASBEE: S for excellent, A, B+, B- and C for poor (Appendix 7). This calculation method makes it difficult to understand the value of each credit until the final score (BEE_{HI}) has been calculated.

5.2.1 Assessment model

Like CASBEE, this model assess the following building types:

- non-residential: offices, schools, retail, restaurants, halls and factories;
- residential: hospitals, hotels and apartment blocks.

For the purpose of this study, we will assume that it also included the detached house (CASBEE-HD).

5.2.1.1 Local framework

CASBEE-HI is built around building's surrounding conditions and density. These influence the site micro-climate, especially wind flow and mean ambient temperature.

The model sets out three local site characteristics:

SC 1. Very few open spaces around the building site;

SC 2. The building site is next to waterfront, large park, etc;

SC 3. The building site is next to large open space but artificial materials such as wide roadway, etc.

It also includes three building's legal floor area ratios (FR):

a. Low density: FR 200% (with FR < 200%);

b. Medium density: FR 400% (with 200% < FR < 400%);

c. High density: FR 600%covered with (with FR > 400%).

5.2.1.2 Weighting system

To set up allocated weightings for each criteria, a series of simulations tested each three surrounding conditions and three floor area ratios, used the following equations:

L_{HI} is defined by the following equation at the time t:

$$L_{HI\,(t)} = [\,((W_{L1\,(t)} + 0.7\,W_{L2\,(t)}) / c_p) \times \wedge S_{(t)}\,] + [\,W_{L2\,(t)} \times (320/i) \times \wedge E_{(t)}\,] + [\,20\,W_{L2\,(t)} - \wedge M_{(t)}\,]$$

with W_{L1}: ratio of mean ambiant air temperature increase to total L_{HI}

W_{L2}: ratio of SET increase to total L_{HI}

S: Sensible heat flux increases due to the new development within CV (W)

E: Latent heat flux increases due to the development within CV (W)

M: Momentum flux decreases due to the development within CV (kgm/s^2)

Q_{HI} is defined by the following equation at the time t:

$$Q_{HI} = W_{Q\,(t)} \times [\,SET_{limit} - SET_{(x,y,z,t)}\,] \times V$$

with W_Q: probability of human's presence in the pedestrian space (x,y,z)

SET_{limit}: acceptable upper limit of SET

$SET_{(x,y,z)}$: SET value at a point in space defined by x,y and z

V: volume of space where $SET_{(x,y,z)} < SET_{limit}$

with SET: thermal comfort index (Gagge et al. 1971) combination of data obtained by simulation (wind velocity, temperature, radiation and humidity) and assumptions (clothing and metabolism)

The following tables summaries the final weighting:

Surrounding conditions 1		Urban ventilation	Shading	Ground surface covering material	Building materials	Anthropogenic heat from building equipments
QHI	FR 200	0.35	0.23	0.17	0.17	0.08
	FR 400	0.32	0.21	0.16	0.16	0.15
	FR 600	0.30	0.20	0.15	0.15	0.20
LHI	FR 200	0.22	0.21	0.21	0.22	0.14
	FR 400	0.19	0.18	0.18	0.18	0.27
	FR 600	0.15	0.15	0.15	0.15	0.40

Surrounding conditions 2 & 3		Urban ventilation	Shading	Ground surface covering material	Building materials	Anthropogenic heat from building equipments
QHI	FR 200	0.37	0.22	0.17	0.16	0.08
	FR 400	0.34	0.20	0.16	0.15	0.15
	FR 600	0.32	0.19	0.15	0.15	0.19
LHI	FR 200	0.24	0.21	0.20	0.22	0.13
	FR 400	0.21	0.18	0.17	0.18	0.26
	FR 600	0.17	0.15	0.14	0.15	0.39

Fig 5.05 Weighting factors (Mochida, 2006)

5.2.1.3 Indicators

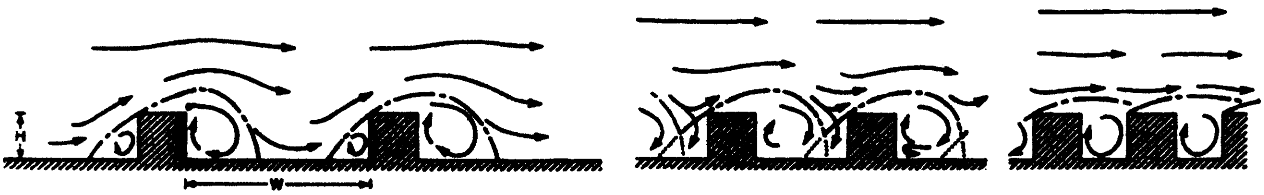
All the issues are split into quality measures (Q) and load reduction (L) for each of the following five main categories (Appendix 7):

- Urban Ventilation

The urban wind patterns are complex: small differences in topography, building arrangement or local features can cause irregular air flow. Oke in Boundary Layer Climates (1987) defined two sublayers:

1. obstructed or urban canopy sublayer; from the ground surface to the building roof top;
2. free-surface or urban boundary sublayer; above buildings height. (Fig 5.08)

Within the urban canopy, pedestrian space could be improved by appropriate building arrangement & geometry such as providing green lanes between blocks (Q1). Directing winds to leeward side of buildings reduces heat release through convection and perturbation in wind patterns (L1). In order to allow the wind flow penetrating in the urban canopy, the buildings heights need to be lower than the spacing (streets/back gardens) or as a massing exercise a combination of low and high buildings should be introduced.



(a) Isolated roughness flow   (b) Wake interference flow   (c) Skimming flow

Fig 5.06 Flow regimes associated with different urban geometries (Oke, 1987, p267)

Wind speeds are generally lower over cities than over rural areas, which correlated with the typical roughness length analysis of urbanised terrain (Fig 5.07).

Terrain	z_0 (m)
Scattered settlement (farms, villages, trees, hedges)	0.2–0.6
Suburban	
Low-density residences and gardens	0.4–1.2
High density	0.8–1.8
Urban	
High density, < five-storey row and block buildings	1.5–2.5
Urban high density plus multistorey blocks	2.5–10

Fig 5.07 Typical roughness lengh z_0 of urbanized terrain (Santamouris, 2001, p35)

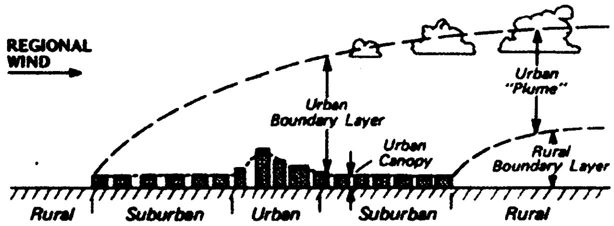


Fig 5.08 Schematic representation of the urban atmosphere illustrating a two-layer classification of urban modification (Oke, 1987, p274)

In addition wind has a great influence on the ventilation strategy and determining the potential for natural ventilation.

- Ground surface covering materials

The surface properties of covering materials have a direct impact on the cooling loads of buildings and on the UHI. Within the pedestrian space we should aim to reduce the asphalt or paved area and replace it by green elements and water body (Q3); around building high permeability and solar reflectance materials are preferred (L3); in order to:

1. reduce the mean albedo; this term describes 'the proportion of total incident radiation that is reflected; integrated over all wavelengths' (Graves, 2001). It depends on the angle of radiation incidence, defined as normal incidence (refer to 2.1.1). High reflective surface such as snow has an albedo of 0.9, which indicates that it reflects 90% of the solar radiation; deciduous plants reflects 20-30% compare to Asphalt with only 10-15%. (Fig 5.09)

Mediterranean climate buildings are traditionally painted white to maximise the reflection of sun's rays (Fig 5.10).

2. increase evaporative cooling; the use of vegetation on ground surface or high permeability paving helps to reduce extreme surface temperatures in summer by retaining and releasing moisture to the environment.

	Surface	Albedo*
Streets	Asphalt	0.05–0.2
Walls	Concrete	0.1–0.35
	Brick/stone	0.20–0.40
	Whitewashed stone	0.80
	White marble chips	0.55
	Light-coloured brick	0.30–0.50
	Red brick	0.20–0.30
	Dark brick and slate	0.20
	Limestone	0.30–0.45
Roofs	Smooth-surface asphalt (weathered)	0.07
	Asphalt	0.10–0.15
	Tar and gravel	0.08–0.18
	Tile	0.10–0.35
	Slate	0.10
	Thatch	0.15–0.20
	Corrugated iron	0.10–0.16
	Highly reflective roof after weathering	0.6–0.7
Paints	White, whitewash	0.50–0.90
	Red, brown, green	0.20–0.35
	Black	0.02–0.15
Urban areas	Range	0.10–0.27
	Average	0.15
Other	Light-coloured sand	0.40–0.60
	Dry grass	0.30
	Average soil	0.30
	Dry sand	0.20–0.30
	Deciduous plants	0.20–0.30
	Deciduous forests	0.15–0.20
	Cultivated soil	0.20
	Wet sand	0.10–0.20
	Coniferous forests	0.10–0.15
	Wood (oak)	0.10
	Dark cultivated soils	0.07–0.10
	Artificial turf	0.05–0.10
	Grass and leaf mulch	0.05

Fig 5.09 Albedos of some typical materials (Graves & all, 2001, p23)

- Building materials

The aim is to reduce heat flux into buildings (L4) and pedestrian spaces (Q4) by introducing green-roof & green-wall or high solar reflectance & low emittance covering materials (Fig 5.11). A high albedo surface may only be effective in reducing heat gain if its emissivity is also high. For example metallic surfaces such as aluminium emit more long-wave radiation than a matt grey paint.

- Shading

Shading should improve the thermal environment in pedestrian space (L2) and reduce the solar gain to the building (Q2). This mitigation strategy should aim to reduce peak cooling loads without compromising daylighting. Solar shading strategies will mainly depend on the orientation; South facing openings should introduce overhang, canopies or deep reveals to protect from high-angle solar radiation; while West and East openings need moveable vertical fins or shutters to protect against the low-angle radiations. Combining these options with high-performance glazing (tinted, low-emissivity or films) will provide an effective solution: controlling solar gain and reducing sun glare. Surrounding vegetation should also be taken into consideration in the pedestrian space and used in conjunction with piloti, eaves and pergolas (Fig 5.10).

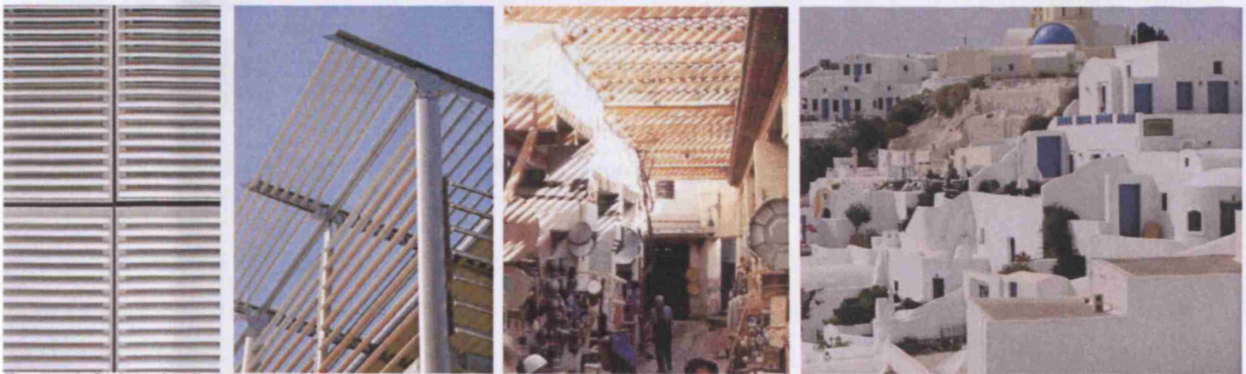


Fig 5.10 Solar shading by Levolux (www.levolux.com). Moroccan market (http://photos.igougo.com/pictures-photos-l235-s2-p3786-Moroccan_market.html). Fira Santorini (www.arataphotos.com/turkeygreece.php)

Fig 5.11 Green walls in Japan and Paris (www.murvegetalpatrickblanc.com). Green roof (http://earthobservatory.nasa.gov/Study/GreenRoof/greenroof3.html)

- Anthropogenic heat releases from building equipment

The first aspect to consider is to improve the thermal environment in pedestrian space by considering the locations of inlets and outlets (Q5). The location and number of windows depends on the ventilation and daylighting requirements but also to fulfil aesthetic criteria and provide a view. HVAC vents require good quality air at the inlet and should avoid pollution at street level or contamination from the exhaust. The location of vents is also influenced by wind pressures which vary with the building geometry (fan location and performance). AC inlets should be away from areas with high surface temperature or receiving direct solar radiation. The exhaust should be placed in a location that is well ventilated and at a higher point than the inlet; roof level (Fig 5.12)

The second aspect is to reduce the amount of anthropogenic heat releases to the atmosphere (L5). This relates to a well insulated building fabric which prevents heat loss. Energy efficient building systems reduce casual gains and should be combined with heat-recovery systems and district heating or cooling which utilize energies such as exhaust heat from incineration plant or waste heat from sewage plant. Also the exhaust air temperature from building equipment should be reduced. Finally the peak of the anthropogenic heat released could be shift by utilizing the heat storage system.

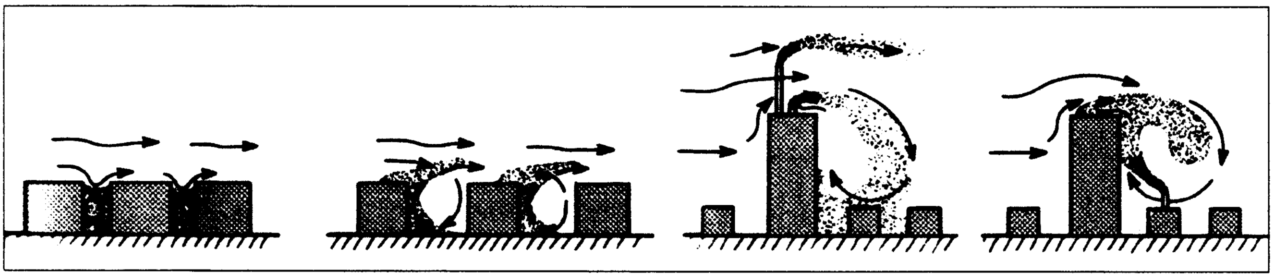
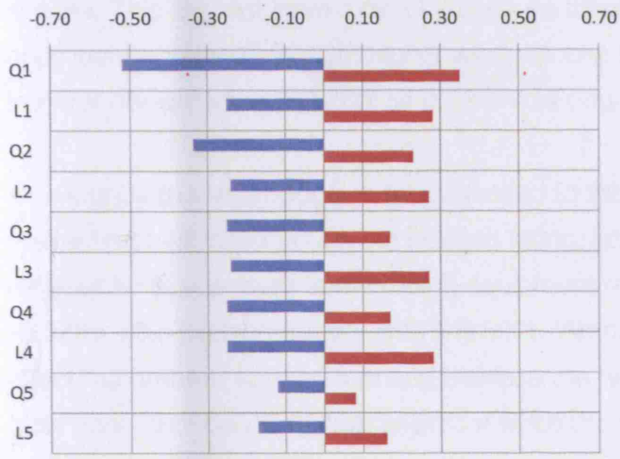


Fig 5.12 The influence of building air flow on pollution dispersion. (Oke, 1987, p273)

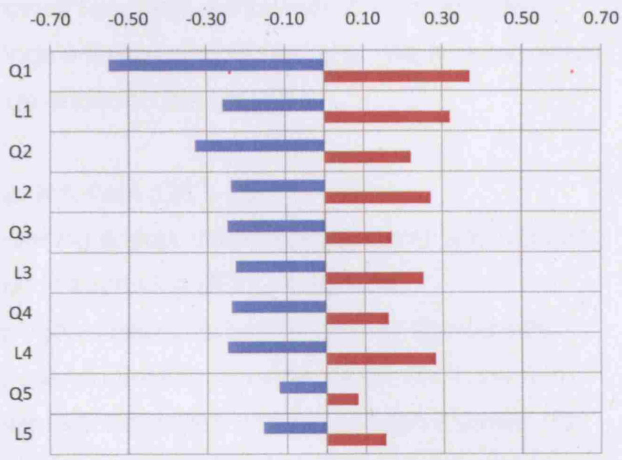
The five indicators listed above are part of CASBEE-HI assessment tool. Some seem to be location specific (Japan) or just not common practice in London, such as utilizing waste heat from incineration plant, sewage plant or seawater, river water and groundwater. On the other hand some indicators could be added to the list such as maintenance strategy of green roofs and targets setting the minimum SRI level of roofing reflective surface. As we would expect this list is non-exhaustive and could be refined while taking into account London context. CASBEE-HI is the only tool available to specifically assess the UHI effect; that is why we will use this method to assess our case studies in the following chapter.

5.2.2 What affects CASBEE-HI ?

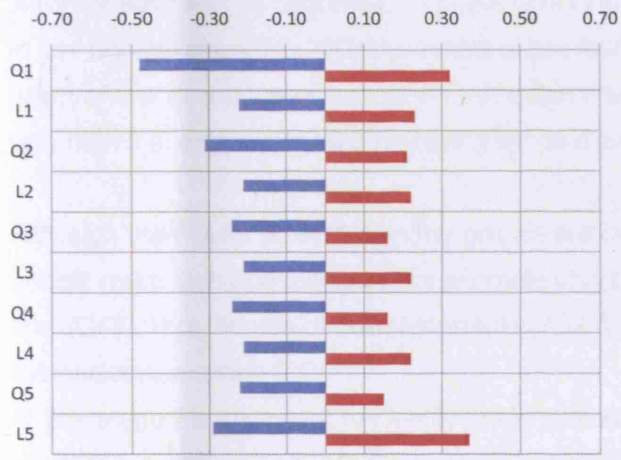
In order to analyse the current model, the following sensitivity study tested the five CASBEE-HI indicators for each site condition and floor area ratio. The variation range of BEE_{HI} is as follows:



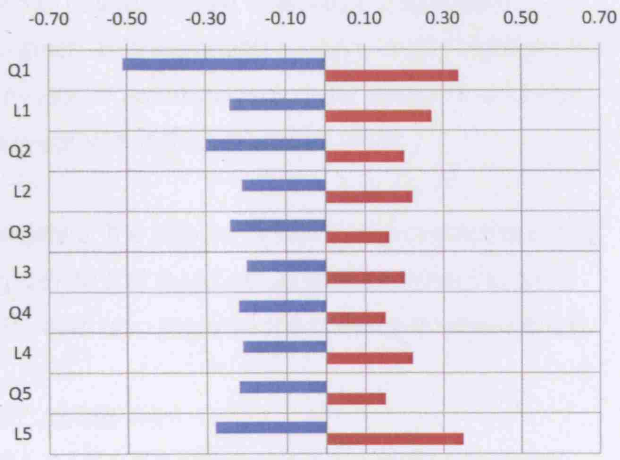
Site contions 1 with FR 200



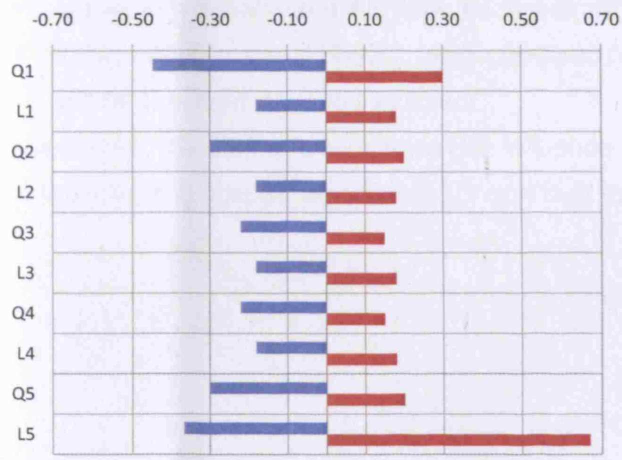
Site contions 2&3 with FR 200



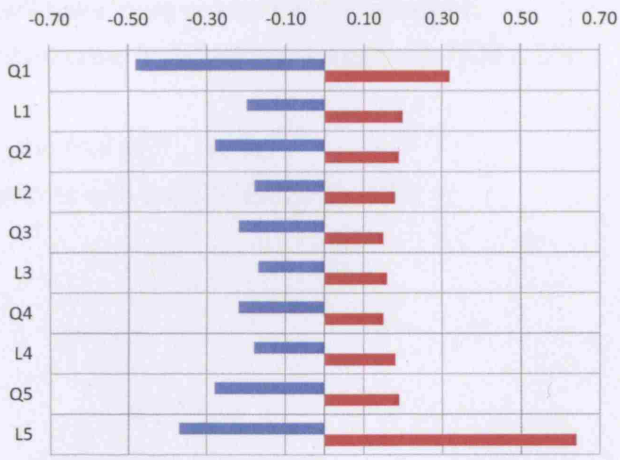
Site contions 1 with FR 400



Site contions 2&3 with FR 400



Site contions 1 with FR 600



Site contions 2&3 with FR 600

Fig 5.13 Range of variation in BEE rating for each site conditions and floor area ratio

From these graphs we can observe that the most determinant indicators are:

- Urban Ventilation to pedestrian spaces (Q1 & L1)

One of the biggest variation in BEE_{HI} rating occurs as a result of changes to the building arrangement. By fragmenting the building or creating green lanes, the wind flows more easily in the pedestrian spaces. This may not have a direct impact on the external temperature however it is an adaptive approach to thermal comfort: higher wind velocity brings a feeling of cool draught. This is determinant in lower density areas (FR 200) as 0.92 points could be added to the final BEE_{HI}.

- Reduce the anthropogenic heat released to the atmosphere (Q5 & L5)

Preventing heat loss through the building fabric, introducing energy efficient AC systems and reducing exhaust air temperature from building equipment result in improving BEE_{HI} rating from -0.37 to +0.67 in high density area (FR 600). 'Anthropogenic heat in urban areas may significantly affect the ambient temperature and increase the heat-island intensity'. (Santamouris, 2001, p41) In New York, anthropogenic heat is almost twice the solar radiation input, while in London it varies with the seasons. The energy balance is dominated by anthropogenic energy during the winter, while in the summer solar energy becomes dominant unless in urban cayon context (Hamilton, 2007, p51).
In low density areas (FR 200) this indicator has little impact. This weighting strategy might highlight the effect of low canopy layer conditions. Although the amount of anthropogenic heat released could be very high (i.e. data centre) the prevailing winds play a greater part than in dense areas.

Although the results presented in the graphs are cumulative; the effects of some improvements could benefit more than one category; for example shading device (Q2 & L2) could also improve the wind flow (Q1&L1) or the use of trees for shading (Q2 & L2) could also improve the thermal environment in the pedestrian space (Q3).
At this stage it is important to identify the limitation of CASBEE-HI:

- in low density area (FR 200): 'urban ventilation' (Q1 & L1) will be the most influential indicator;
- in medium density area (FR 400): each indicator will have more or less the same weight;
- in high density area (FR 600): 'anthropogenic heat releases from building equipments' (Q5 & L5) will be the most influential indicator.

Meanwhile, the site conditions have little influence on the final BEE_{HI} results.
In the following chapter we will test London built examples with the CASBEE-HI model.

VI. Modelling and results

Each micro-climate is generated by small-scale features such as buildings or trees; combined together they influence larger climates such as the heat island. In order to define which building type should be analysed in detail, we need to look at London land use (Fig 6.01).

65% of London 1,600 square kilometres is occupied by domestic gardens, green spaces and water (rivers, lakes and pounds). 'Around a third of this is private gardens, another third is parks or sports-use and the remaining third is wildlife habitat' (MOL, 2007, Ch 6). Another 14% is covered by roads, rail and paths; and only 14% is occupied by buildings or 1/7 of London's land. The percentage of land use by building can go up to 45% in the City of London and as low as 7% in Bromley or Havering.

The anthropogenic heat release is linked to the building use in terms of frequency and intensity.
In London 63% of the building stock are of residential use (C3) and 37% are non-domestic. This includes commercial (A) and industrial (B) premises but also hotel (C1), institutional (D1), assembly & leisure (D2) and Sui Generis (SG) to follow the UCO classification (Appendix 8). City of London has the highest percentage of non-domestic building at 83% followed by Tower Hamlets at 60% and City of Westminster at 58%; while Bromley, Harrow and Redbridge are close to 20% (Fig 6.03).

The main dwelling types in London are terrace and purpose-built flat or maisonette with 31% each then semi-detached at 19%, conversion at 13% and detached with only 5% of the residential stock (Fig 6.02). With regards to commercial and industrial premises, 48% are retail premises (A) and 41% offices (B1), only 12% factories (B2) and 11% warehouses (B8) (Fig 6.04).

From these results, the case study will analyse in detail residential buildings built before and after 1995; and offices built in the last 10 years.

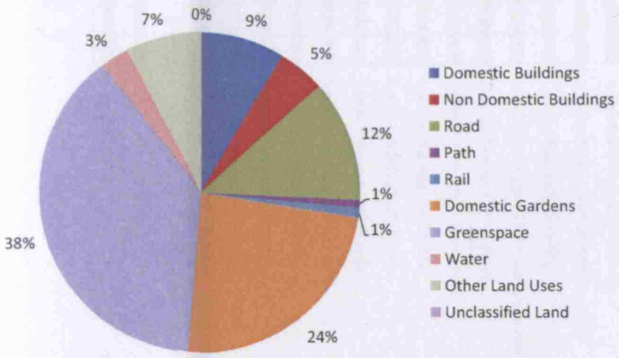


Fig 6.01 Land Use in London
(CLG, Generalised Land Use Database, 2007)

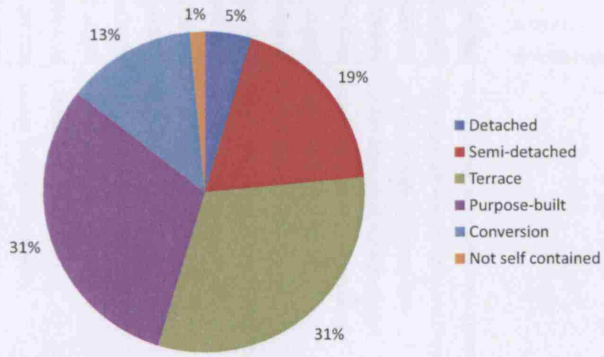


Fig 6.02 Dwelling stock per type of accommodation in London (CLG, 2007, Table 117)

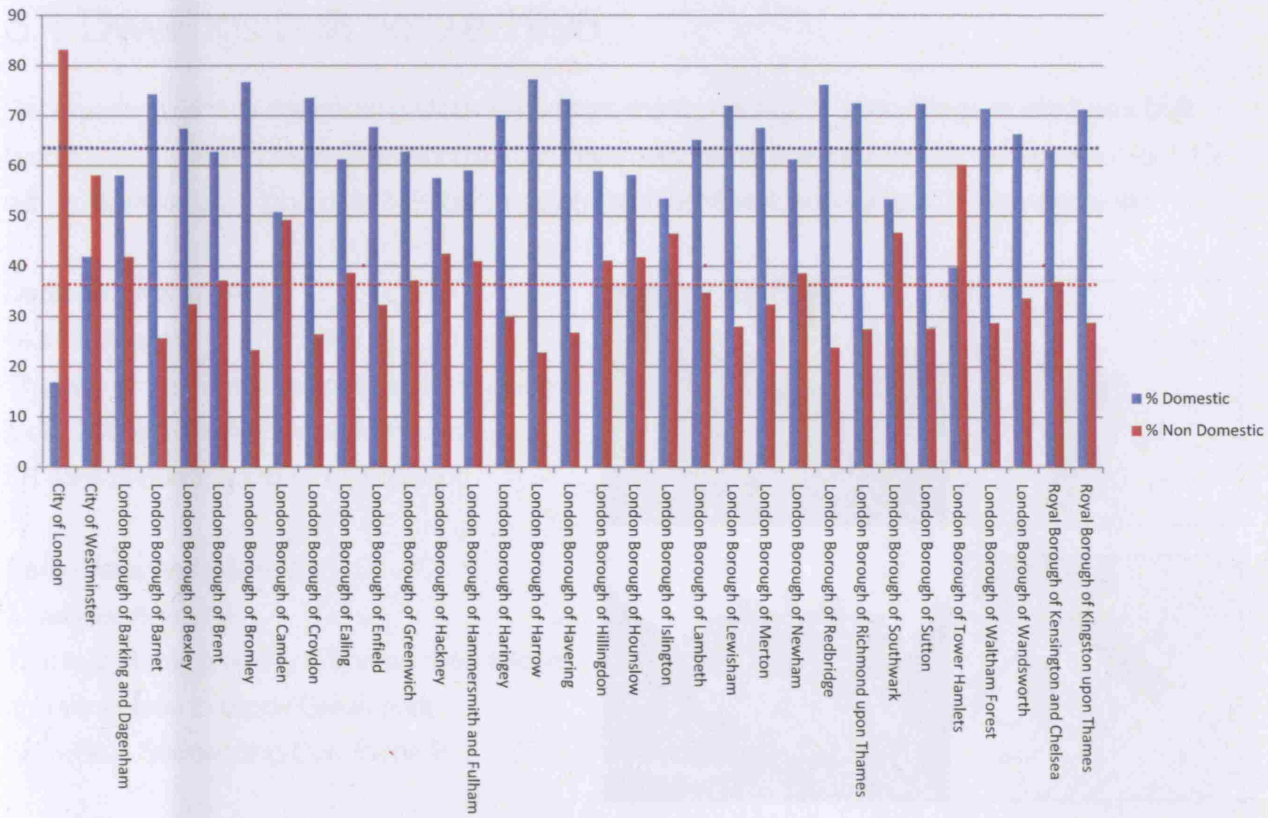


Fig 6.03 Percentage of domestic and non-domestic buildings per London Borough (CLG, Generalised Land Use Database, 2007)

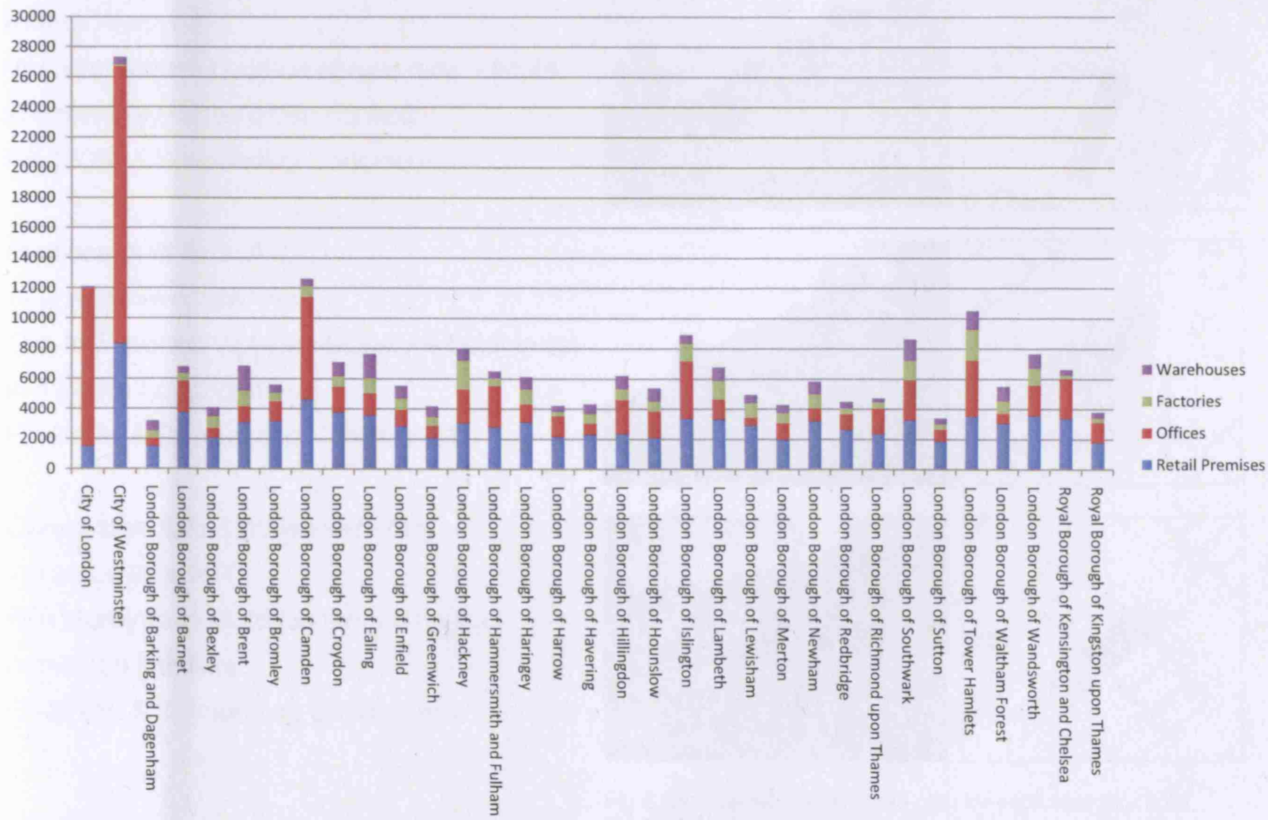


Fig 6.04 Commercial and Industrial Floorspace and Rateable Value Statistics per London Borough (CLG, 2007)

6.1 Dwellings built before 1995

Representing 96% of the housing stock in London, the first category of dwellings studied was built before 1995. I have chosen 5 developments in Hammersmith which is a relatively dense area (Fig 2.15) with a representative land use; 24% buildings of which 59% residential and 41% non-domestic.

Detached house (A1)

14 Book Green W6

This two storey Victorian house is set in a large plot 1260m² with direct view to the park.

FR 45% & Surrounding Conditions 3

Semi-detached house (A2)

3 Caithness Road W14

This two storey property is spread over 4 floors and very close to Brook Green park.

FR 83% & Surrounding Conditions 2

Terrace house (A3)

6 Milson Road W14

Victorian terrace house is spread over 4 floors in a relatively dense urban context.

FR 180% & Surrounding Conditions 1

Purpose built flats (A4)

19 to 26 Richmond Way W14

This four storeys Victorian Mansions bock is set in a dense housing area.

FR 230% & Surrounding Conditions 1

Conversion flats & maisonette (A5)

119 Sinclair Road W14

Five storey large Victorian terrace house converted into flats.

FR 220% & Surrounding Conditions 1

Fig 6.05 External view and site plan for each category from dwelling A1 (top) to A5 (bottom)

CASBEE-HI was used to analyse the mitigation strategies of the five residential buildings near Hammersmith; the overall scores are relatively low; the conclusion are as follow (Appendix 9)

- all the dwellings score high in two categories:

1. 'Ground surface covering materials' (Q3-L3) as most of the remaining land is used as private gardens;
2. 'Anthropogenic heat releases from building equipments' (Q5-L5) result of the ventilation strategy: the dwellings are naturally ventilated.

- low scores are register to:

1. 'Urban Ventilation' (Q1-L1) wind conditions do not seem to be taken into consideration in the building arrangement, especially directing airflow to the leeward site;
2. 'Building materials' (Q4-L4) no green roof or balcony for planting and most of the external walls or roof are of low albedo material.

For each site, the table below shows BEE_{HI} predicted results. All the dwellings are in C or 'poor' category.

The FR ratio for these sites is 200% or 400% which means that the first item 'Urban Ventilation' has a strong impact on the final result. Unfortunately the five buildings score low on this point, as the streets are not planned around wind flow but around two boundaries: a park and a train line. This Victorian arrangement relates to:

- Efficiency, maximum use of the land _the ratio between building height and street width is maintained (1:1 to 2 : 1). Building height is defined by the construction type and the usage; street width by the size of a car;
- SE-SW or NE-NW orientation, each room should receive direct sun light once a day (hygiene).

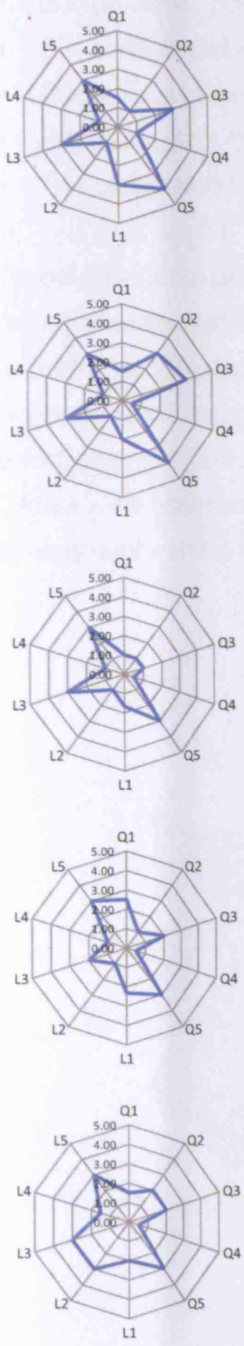


Fig 6.06 Graph mapping the final score for each category from dwelling A1 (top) to A5 (bottom)

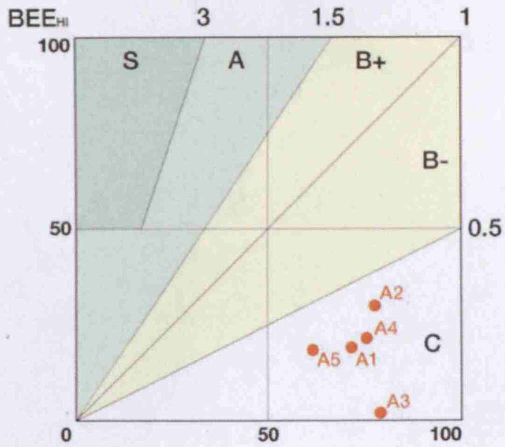


Fig 6.07 BEE_{HI} Graph for all dwellings, A1 to A5

6.2 Dwellings built after 1995

The second category of dwellings was build after 1995. Representing only 4% of the housing stock; these case studies take into consideration the recent planning guidance and Building Regulations. I have chosen five developments across Central London:

- B1: detached house, 9 Stock Orchard Street N7 Islington;
- B2: semi-detached house, 6 Stamford Brook road W6 Hammersmith & Fulham;
- B3: terrace house, Leonard Place & 19 Allen Road N16 Hackney;
- B4: purpose built flats, Lant Street SE1 Southwark;
- B5: conversion flats & maisonette, Lawn Road NW3 Camden.

These exhaustive examples show different modalities (Brandon & Lombardi, 2005): project's scale, number of residents, layout, shape, building material, building footprint, ground structure, air & water quality, biodiversity, location, noise level, transport, mobility & accessibility, wellbeing and heritage. This description reveals part of the diversity and the complexity of urban environments in which micro-climate such as heat island occurs. The following analysis is based on CASBEE-HI assessment. Only a synthesis of the results is presented in this section although B1 full assessment can be follow in Appendix 9.

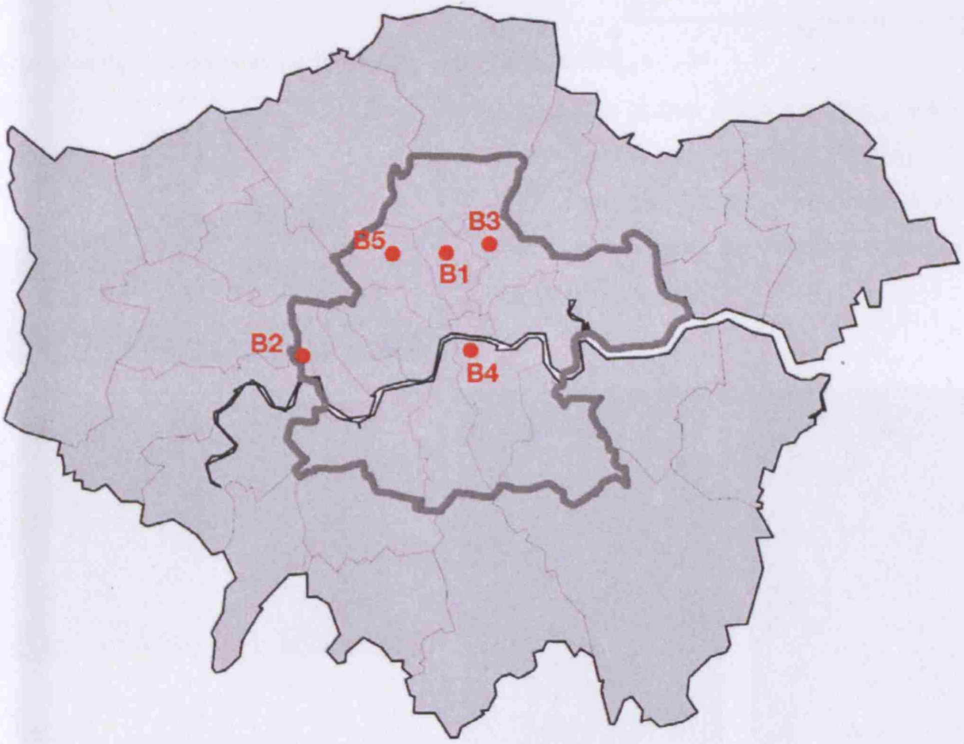


Fig 6.08 Location map for all dwellings, B1 to B5

Detached house 2004 (B1)

9 Stock Orchard Street N7 Islington

Sarah Wigglesworth Architects & Price and Myers

www.swarch.co.uk

FR 60% & Surrounding Conditions 2

A lively contrast of materials, colours, and forms characterise this project. The house and associated office use innovative technologies based on sustainable design. These include a system of walling incorporating straw-bales. The living accommodation is raised up to allow a garden at ground floor; the roof is also planted and irrigated by collected rain water solar-pumped. The central tower acts as a thermal flue, catching the wind and encouraging natural ventilation to cool the house in the summer. In a dense urban context, the office fronts a railway line and is faced in sandbags for acoustic protection.

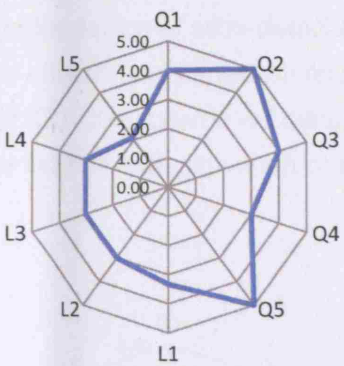


Fig 6.09 Graph mapping the final score for each category

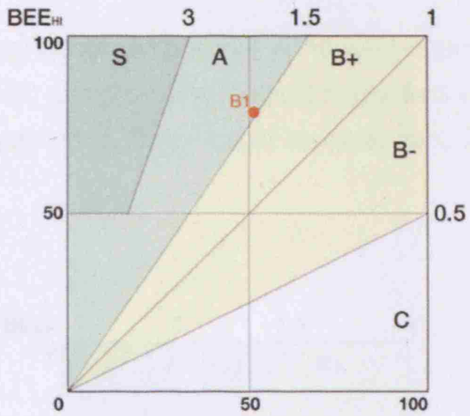
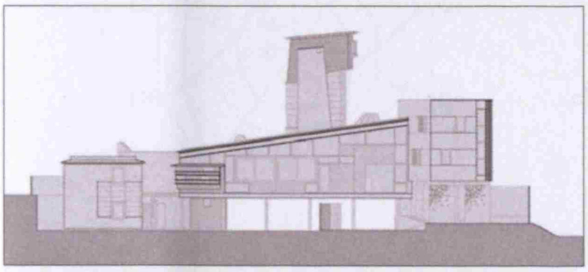
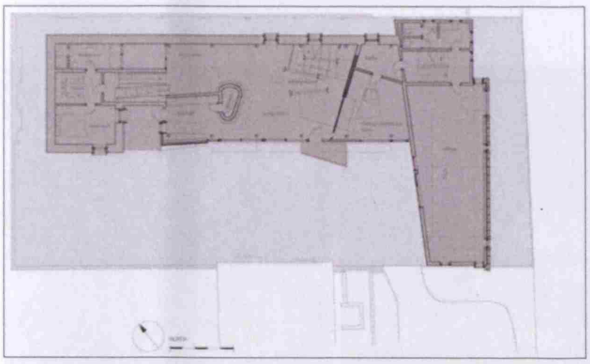


Fig 6.10 BEE_{HI} = 1.54



The graph above shows a BEE_{HI} result of 1.54 which is in A, 'very good' category. To improve this score, the project could have included heat recovery systems for ventilation and heating or to produce electricity.



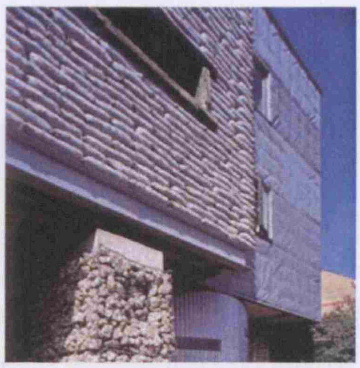


Fig 6.11 9 Stock Orchard Street first floor plan, section and detail pictures.

Semi-detached house 2002 (B2)

6 Stamford Brook road W6 Hammersmith & Fulham

Powell-Tuck Associates, Whitby Bird & E+M Tecnica

www.powelltuck.co.uk

FR 62% & Surrounding Conditions 1

Approached under an archway and down a cobbled alley-way, these joined family houses sit on former factory grounds. In this backyard site and dense urban context, the scheme is playing with privacy and overlooking issues. A series of courtyards and high level windows maximise gardens spaces and daylighting. Forming an L-shape, the interlocking houses use brick, glass and fixed timber louvers as external cladding material. The concrete frame is exposed in the internal space and used as a thermal store. The rooms are larges an always connected with the gardens.

This modernist version of semi-detached house scores 'very good', A category. Although it improves the thermal environment in pedestrian space by shading (Q2) and providing landscape gardens and water body (Q3), the scheme will benefit from the use of green roof. These could be easily retro-fitted in the large flat roof area after a structural survey.

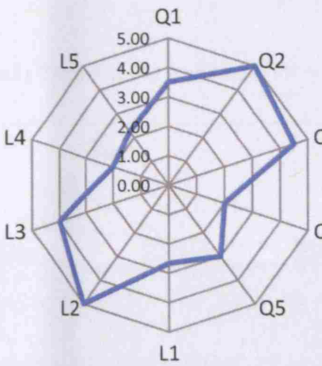


Fig 6.12 Graph mapping the final score for each category

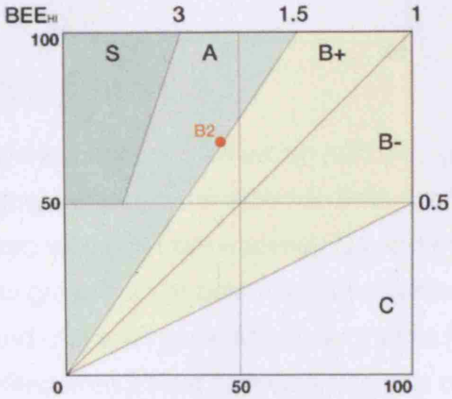


Fig 6.13 $BEE_{HI} = 1.54$

Fig 6.14 6 Stamford Brook road detail pictures.

Terrace houses 2006 (B3)

Leonard Place & 19 Allen Road N16 Hackney

Brady Mallalieu & Price and Myers

www.bradymallalieu.com

FR 85% & Surrounding Conditions 1

A two storey 'Infill' terrace has been designed to fit within a disused brownfield gap on Allen Road. Seven units of L-shaped form avoid overlooking - each house has its main rooms oriented towards the afternoon sun and away from the windows in properties surrounding the site. This provides a protective shell to the rear of the unit and also reflects daylight into the gardens on Clonbrok Road. In contrast the exposed timber frame and cedar shingle elevations give a softer feel to the individual courtyards and gardens.

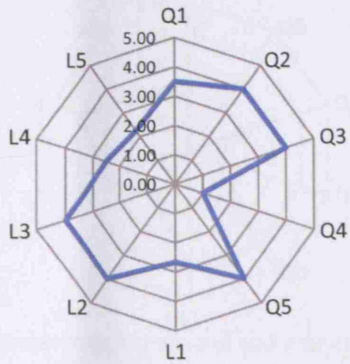


Fig 6.15 Graph mapping the final score for each category

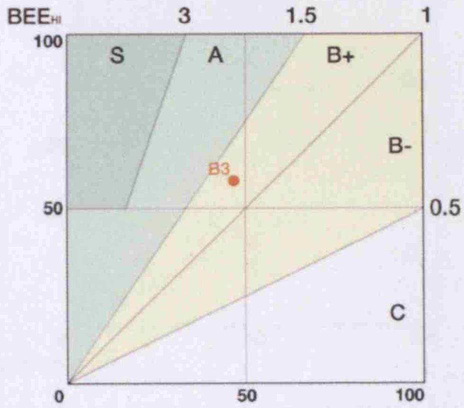
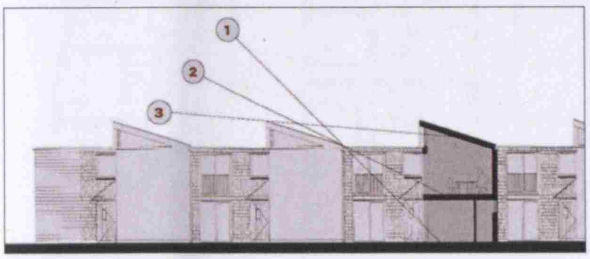


Fig 6.16 BEE_{HI} = 1.24

This project scores 1.24 which is in B+, 'good' category. Although the external walls are covered with reflective material, Q4 and L4 are low as green-roof or balconies with planters are omitted of the scheme. Moreover it would have benefited from a heat storage system to shift the anthropogenic heat released, i.e. at night time.



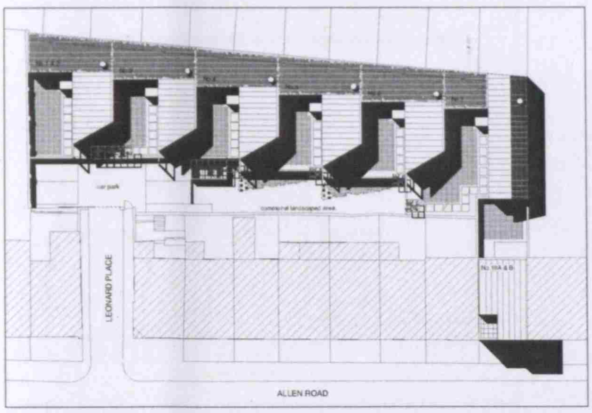


Fig 6.17 19 Allen Road situation plan, section and detail pictures

Purpose built flats 2007 (B4)

Lant Street SE1 Southwark

KMK Architects, NRM Bobrowski & Con-Serv

www.kmkarchitects.co.uk

FR 390% & Surrounding Conditions 2

The project includes 16 apartments (1 to 3 bedrooms), a nursery and underground parking; it overlooks a small park close to the Tate Modern. Separated into two distinct buildings, the unified facade system responds to the orientations. External walls are transparent and full-height openings are solid oak panel. With a system of internal glazed balustrade, these 'windows' open or close subject to the internal environment.

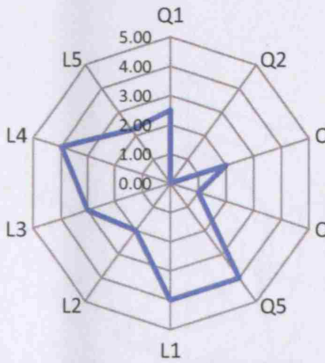


Fig 6.18 Graph mapping the final score for each category

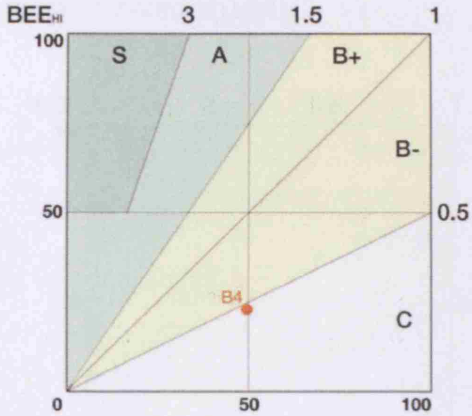
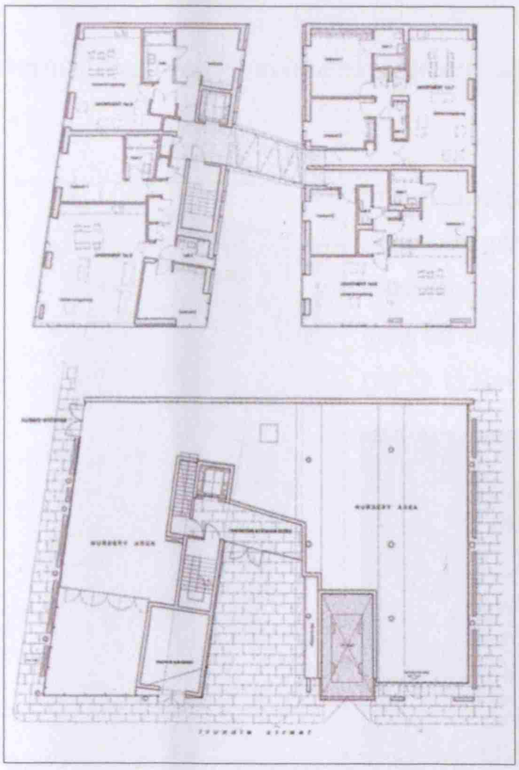


Fig 6.19 BEE_{HI} = 0.46

Just under the 0.5 limit this new purpose built block of flats in Southwark only scores 0.46 in the C category, 'poor'. It could easily improve this score by improving the thermal environment in pedestrian space: creating shade from trees, piloti, eaves and pergola. Also greening or using high reflective surfaces on the South & Western elevation will bring the BEE_{HI} rating to 1.21 in the B+ category.



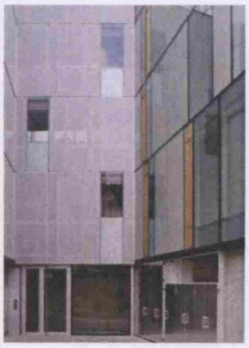


Fig 6.20 Lant Street ground floor plan, third floor plan and overall pictures

Conversion flats 2007 (B5)

Lawn Road NW3 Camden

Avanti Architects, Alan Conisbee Associates & Max Fordham

www.avantiarchitects.co.uk

FR 135% & Surrounding Conditions 2

Isokon mansion block was first completed in 1934 by Wells Coates. After years of disrepair, this recent refurbishment brings the Grade I Modernist landmark up to today's standards and codes. Thin sheets of insulation were utilised in the reveals in order to maintain the original dimensions of the doors and windows. Soffits have been fitted with mineral-wool insulation and acoustic panels. The services were also refitted to follow the new layout: studios and 1 bedroom units.

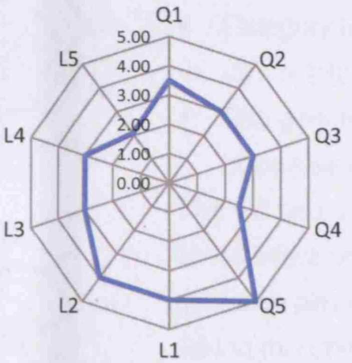


Fig 6.21 Graph mapping the final score for each category

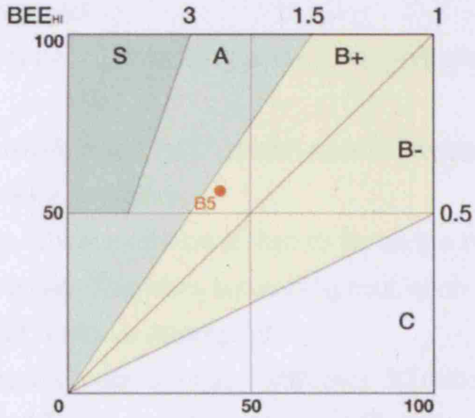
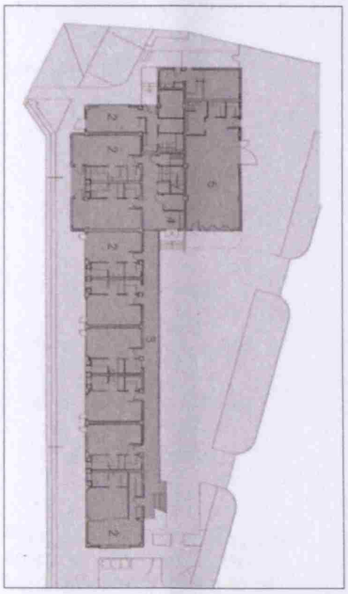


Fig 6.22 BEE_{HI} = 1.36



This project's scores is fairly homogenous, scoring between 2 & 5 on each category, the final BEE is 1.36 which is in B+, 'good' category. Heat storage systems could be introduce to improve L5, greening the external walls by using planters and the roof top (Q4 & L4) will add 1.27 points to the final BEE, or 2.63.

Fig 6.23 Lawn Road first floor plan and overall pictures.

Summary

The fives examples chosen to represent the dwellings built after 1995 score better than their older counterparts; with BEE_{HI} rating between 1.54 to 0.46 and A to C category. In addition these developments could easily accommodate some improvements such as heat storage system, green roof and vegetation in the pedestrian space.

Reviewing the CASBEE-HI indicators give us some direction in criteria to consider for UHI effect mitigations. Although the Codes for Sustainable Homes does not include overheating strategies, it could incorporate the following:

- Category 1 (energy/CO2) heat recovery device, heat storage system, reducing air temperature of exhaust and emitting waste heat at high level;
- Category 1 (energy/CO2) solar shading;
- Category 3 (materials) reflective paving, cladding and roofing material (SRI > 29);
- Category 9 (ecology) green walls & green roof, garden space & water body (use as a rain water store for irrigation);

This will be a nation-wide measure which might be a step to far as the heat island effect only occurs in urban areas. Therefore a planning tool, such as a guidance aim at London only might be more appropriate.

Taking this comment apart, England is a dense region with over 50 millions habitants living in 130,395 km², or 388.7person/km² (National Statistics & Wikipedia). This is comparable to Japan with 337/km², three and half time as much as France with 114/km² and twelve time more than the US with 31/km². (Wikipedia)

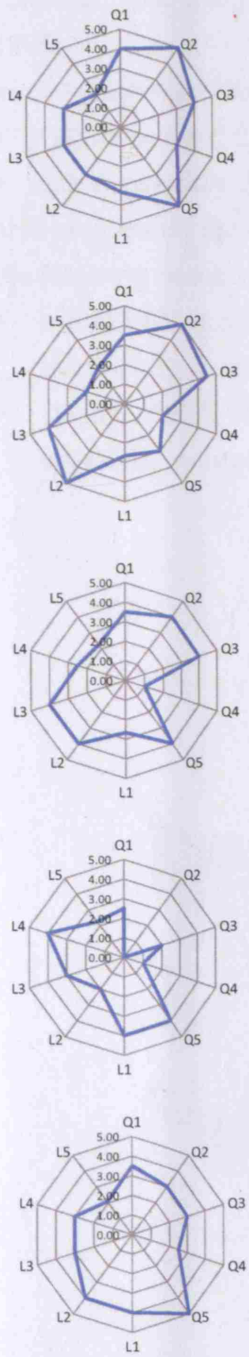


Fig 6.24 Graph mapping the final score for each category from dwelling B1 (top) to B5 (bottom)

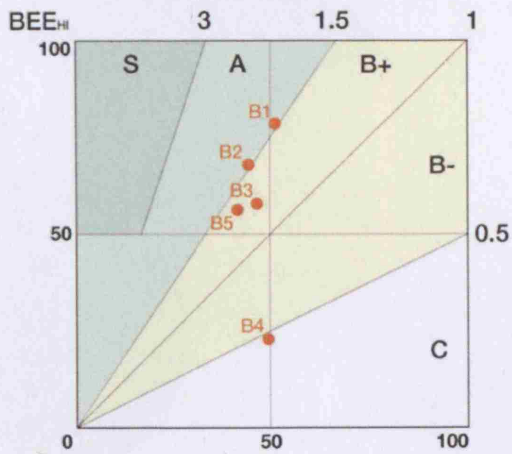


Fig 6.25 BEE_{HI} Graph for all dwellings, B1 to B5

6.3 Offices built after 1995

The 'non-domestic buildings' represent 35% of London's built environment (CLG, 2007). In three boroughs, Tower Hamlets, City of London and City of Westminster, this category forms the majority of buildings. CLG survey dated 2007 shows that in these three cases office developments are the most common type. Using CASBEE-HI model this chapter will assess the following office projects built after 1995:

- O1: high rise office tower, 22 Leadenhall Street EC3 City of London (Appendix 9);
- O2: office park, Chiswick High Road W4 Hounslow;
- O3: conversion, 38 Fitzroy Square Boston House W1 Camden.

This exercise will assess the three schemes in their ability to mitigate UHI effects; it will also address the following questions (based on Brandon & Lombardi, 2005):

- Is CASBEE-HI able to produce meaningful results for each development: different location, design, biodiversity, location, accessibility, heritage, etc?
- Does CASBEE-HI produce clear advice for decision-maker: understanding the issues, suggesting solutions, monitoring the progress and improving the scheme?

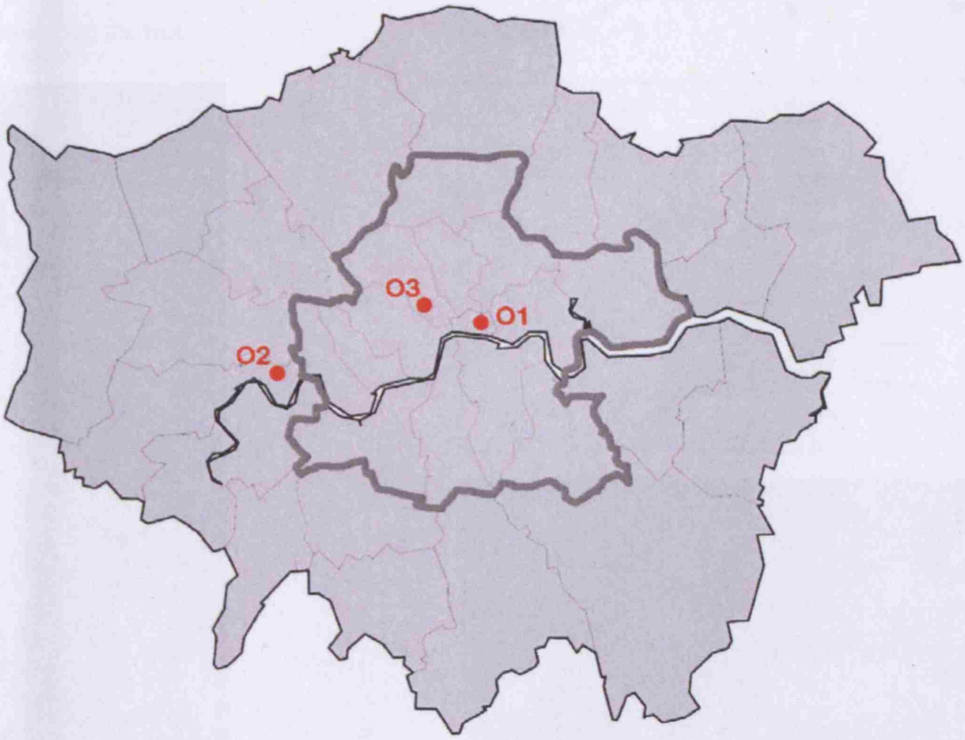


Fig 6.26 Location map for all dwellings, O1 to O3

High-rise office tower 2001-2011

122 Leadenhall Street EC3 City of London

Rogers Stirk Harbour + Partners & Arup

www.rsh-p.com

FR 2800% & Surrounding Conditions 1

The 52 storey tower (239.4m AOD) has been designed to protect views of St Paul's Cathedral from Fleet Street. The rectangular floor plates slope back on the south face to create a distinctive tapering profile. Its structure takes the form of a braced 'tube' which becomes a major visible feature of the building behind its external glazing. On the north side, the building's services and lifts are contained within a separate structural element, ladder frame, to maximise net floor space. The base of the tower will form a six-storey open space with shops, cafes and restaurants; this pedestrian route links eastwards to the remaining plaza.

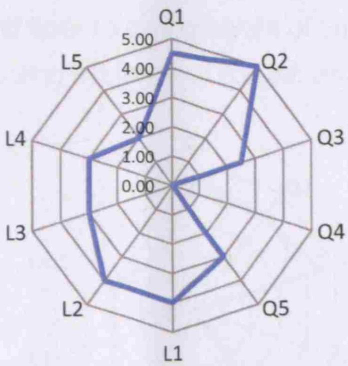


Fig 6.27 Graph mapping the final score for each category

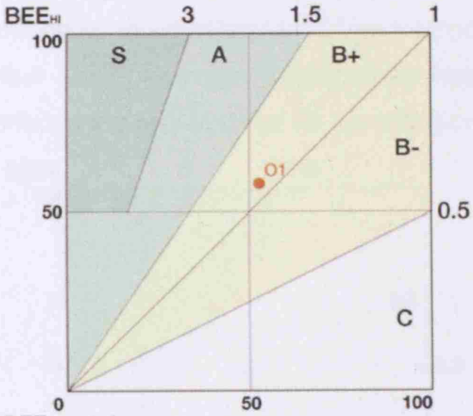


Fig 6.28 $BEE_{HI} = 1.1$

Fig 6.29 Leadenhall Street situation plan and visuals.

Office park 1999-ongoing

Chiswick High Road W4 Hounslow

Rogers Stirk Harbour + Partners & Arup

www.rsh-p.com

FR 142% & Surrounding Conditions 2

The individual buildings at Chiswick Park are arranged around a central linear parkland with water feature. Canopied timber boardwalks form the entrance to each building which face one another. Shortly after entering the site, all vehicular movement is routed behind the buildings. Car parking spaces are screened by planting at the rear and in undercroft areas. Designed for pedestrians, 75% of the users arrive on foot, by bicycle, bus or train. Built in phases, 6 of the 12 buildings were completed in 2002. Full height, glazed central atria provide views out into the park and bring natural light into the office space. The depth of each building varies, as determined by the masterplan. Large internal areas and floor to ceiling height of 3m creates a bright internal feel. The space uses displacement heating/cooling system and natural ventilation, this significantly reduces the requirement for air-conditioning.

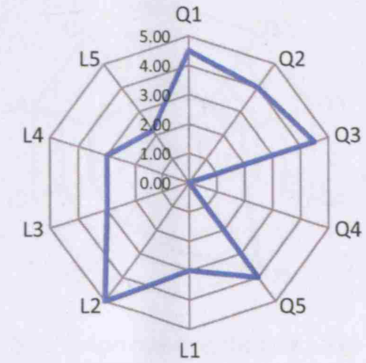


Fig 6.30 Graph mapping the final score for each category

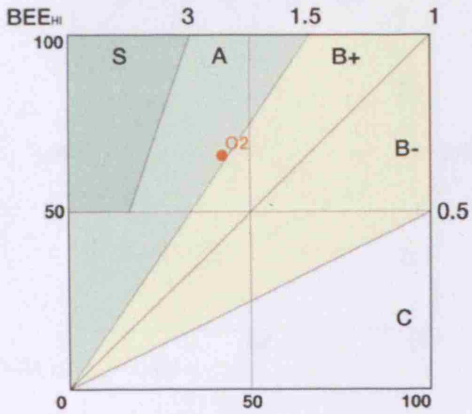


Fig 6.31 BEE_{HI} = 1.56

This project has a contrasted profile, with BEE_{HI} 1.56 in the A category, 'very good'. It should review its strategy toward the thermal environment in the pedestrian space by greening external walls and roof (Q4). Improving its cooling systems (efficiency and high storage system) (L5) will raise BEE_{HI} to 2.34.

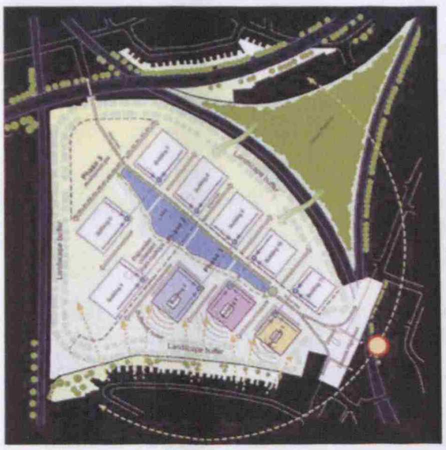


Fig 6.32 Chiswick Park situation plan and overall pictures.

Conversion 2005

38 Fitzroy Square Boston House W1 Camden

Arup Associates, AUD and Arup Sport

www.arup.com/associates/AA_Intro

FR 425% & Surrounding Conditions 2

When work started in 1794, Fitzroy Square was a speculative development intended to provide London residences for aristocratic families. This Grade I listed buildings now houses three departments of Arup. Recently refurbish, its central atrium open onto a communal decked terrace. The high ceilings, open plan office are naturally ventilated. Fronted in Portland stone, the Georgian square is mainly pedestrian. Design by Sir Geoffrey Jellicoe it currently undertakes a major refurbishment, which should be completed by the end of the year.

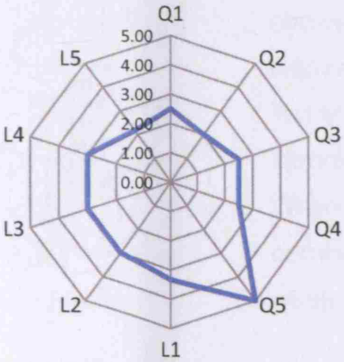


Fig 6.33 Graph mapping the final score for each category

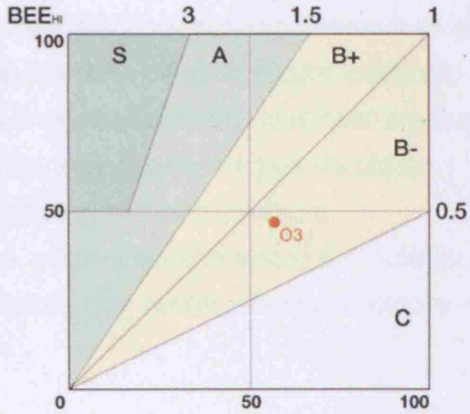


Fig 6.34 $BEE_{HI} = 0.83$

Despite its homogenous profile addressing each indicator, this conversion only achieves BEE_{HI} 0.83, B- in the 'rather poor' category. To improve on Q2, it should to create shades in the pedestrian space by introducing trees, piloti, eaves or pergola. This could only be achieved by re-modelling the square.

Fig 6.35 Fitzroy Square visuals and detail pictures.

Summary

To follow on the CASBEE-HI assessments, the office developments score from 1.56 to 0.83 BEE_{HI} which relate to A to B- category.

To reduce their effect on the UHI, they should consider:

- improving their pedestrian space thermal environment by greening (Q4);
- reducing the anthropogenic heat releases to the atmosphere (L5).

On this last point, the heat released into the environment by buildings and also traffic contributes to a mean temperature rise. Generally, commercial and industrial activities generate more emissions than housing due to their activity or their HVAC strategy. In a recent study published by GVA Grimley (2008) the business's carbon emissions per occupied sq m are highest in central London. (Appendix 10) We can observe a similar pattern in the temperature distribution across London.

With regards to the effect of the heat island on cooling, Graves & all. (2001) shows that it is 12% greater than the peak demand in rural locations. The warmer it gets the more cooling is required and the more heat is generated. To mitigate the impact of this cycle, adaptive techniques should be introduced such as evaporative cooling and air movement.

When required by the occupants, efficient cooling systems should be used; combined with heat-recovery devices they could generate electricity from wasted heat.

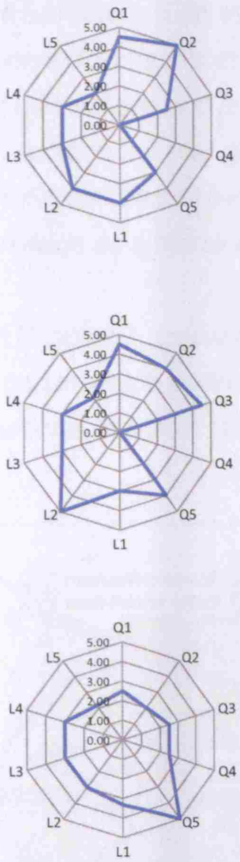


Fig 6.36 Graph mapping the final score for each category from offices O1 (top) to O3 (bottom)

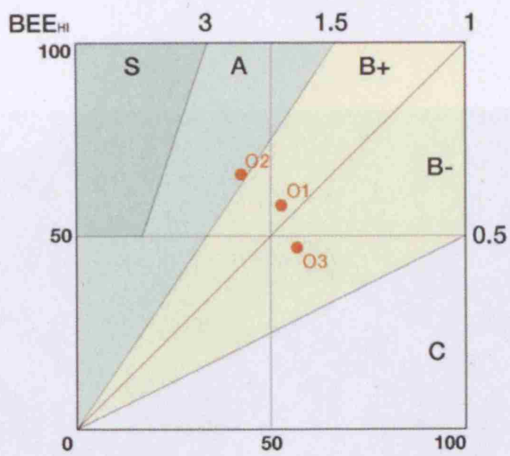


Fig 6.37 BEE_{HI} Graph for all offices, O1 to O3

6.4 Summary

This chapter has outlined the issues related to CASBEE-HI assessment process. In particular it has drawn attention to the poor performances of the buildings studies:

- dwellings built before 1995 with BEE_{HI} inferior to 0.49 in the 'poor' category C;
- new dwellings (built after1995) with BEE_{HI} averaging 1.23 in the 'good' category B+;
- new offices with BEE_{HI} averaging 1.16 in the 'good' category B+.

CASBEE-HI is able to produce a meaningful result for each development. These can be compared and analysed as suggested improvements are drawn.

This tool is currently the only model of this type considering the UHI effects. In order to be used effectively it must be systematically applied as its scoring system is complex. For each indicator, assumptions are drawn to identify a score of 1 to 5, this is a personal choice which leads to partial results. A straight-forward yes/no or 1/0 system might be more suitable.

Another limitation of CASBEE-HI is the use of indicators which are specific to Japan. In the UK and particularly London, some re-cycling technologies are rarely used, such as using waste heat from incineration plant, sewage plant, river and groundwater. On the same subject, high-performance infrastructure such as district heating and cooling are the exception and only form part of the most recent developments. Also the surrounding conditions and floor ratio weighting are defined by a series of calculations and analyses based in Japan. These might not be transferable to London.

In addition this tool gives better rating to high-rise buildings with large open spaces as outlined by Professor Shuzo Murakami presentation (2006) (Fig 6.38). The assessment framework should not privilege as a massing strategy but only suggest improvements to suit any development.

In Chapter 7, a new assessment tool will be proposed in order to provide a specific framework for London which could be used to demonstrate compliance with London Plan Policy 4A.10 and the National Indicator 188.

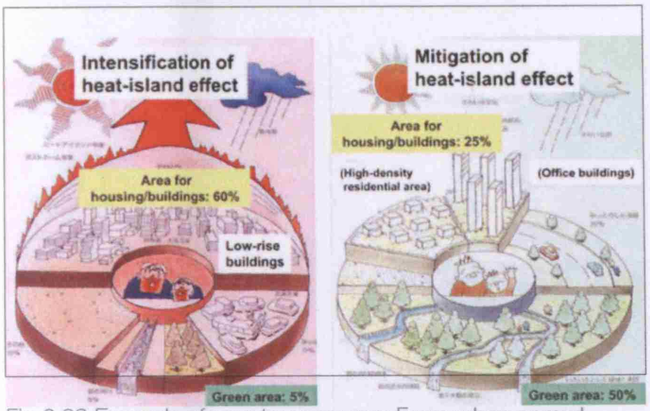


Fig 6.38 Example of countermeasures: From urban sprawl to compact city (Murakami, 2006)

Fig 6.39 Le plan Voisin from Le Corbusier: re-planning Paris in 1925 (www.nyu.edu/classes/reichert/sem/city/lecorbu_img.html)

VII. Analysis

In London, the UHI effects should be considered throughout the design process; especially with regards to orientation, external materials and building systems. As reviewed in chapter II, 26% of the housing stock was built before 1919 and 82% before 1985; hence the life of a development in London could be over 90 years and certainly over 20 years. For projects long-term sustainability, mitigation strategies should be included in early design stages.
With rapid temperature rises due to climate change, it becomes even more important to build facilities which are comfortable to live or work in and cheaper to run and maintain.

Due to social and economical pressures, projects will continue to be developed in areas prone to overheating. The aim of UHI assessment tool is to mitigate their effect and to reduce their vulnerability. It will take into consideration the following design factors:

- site & layout;
- external building envelop;
- building systems & anthropogenic heat source.

These three main criteria include a series of indicators which form the core of the assessment checklist. Each of them is rated and the final score allows us to compare projects and draw reasonable conclusions.

The aim of this chapter is to develop an assessment tool for projects in London by analysing the CASBEE-HI model results. Used by planners & design teams, UHI checklist should be able assess existing and new buildings.

7.1 Indicators

To evaluate we need enough information to make sensible assumptions. The UHI model output should give a broad approximation which enables us to compare different projects. It should also convey the information quickly and effectively. For these reasons I have chosen to use a similar system as BREEAM and LEED where the indicators are clearly defined and weighted by 1 or 0. Measures are listed below with some Suggested Techniques (ST) taken from CASBEE-HI method or LCCP publications (2005 & 2008). Each ST defines an indicator.

7.1.1 Site & layout

Starting by 'site & layout', the following indicators relate to the urban form and the composition of external land surfaces.

1. Wind: maximise cooling potential
Improve the pedestrian thermal environment and reduce the building impact on external space
(ST) reduce the ratio building height to street width; isolated roughness flow (Fig 5.06)
(ST) create ventilation lanes between buildings by introducing low level vegetation such as lawns, shrubs or privet;
(ST) direct winds to leeward side using building height & geometry as well as intervals;
(ST) reduce buildings aspect ratio against prevailing wind direction in summer;

2. External spaces
(ST) Introduce courtyards with vegetation and water feature to temper the environment;
a. ground covering material
(ST) minimum 50% of the site hard landscape covered with reflective surfaces (SRI > 29) (LEED-NC);
(ST) consider 50% of the site hard landscape covered with gravelled or permeable and porous paving;
(ST) maximise green space arranged down a slope to re-use water run off (LCCP 2005);
(ST) introduce water features such as ponds and fountains with minimal net water use and solar powered pumps to re-circulate water;
(ST) as rainfall becomes more seasonal (UKCIP), certain vegetation species may be more appropriate;
(ST) future maintenance strategy to include rainwater harvesting or grey-water recycling to irrigate gardens and landscape areas;
b. shading
(ST) 50% of pedestrian space shaded by trees, piloti, eaves or pergola in summer (LEED-NC);
(ST) use deciduous planting which shade in summer and maximise solar gain in winter;

7.1.2 External building envelop

This main design factor relates to composition of the buildings surface especialy their thermal and radiative properties.

1. Facade
a. fabric covering material
(ST) increase percentage of facade covered with reflective surfaces (SRI > 29)
(ST) introduce vertical gardens, balconies with planters or climbers, particularly on the South and West facade which receives high solar radiation; future maintenance requirements should be included in the scheme (stored rain water or grey water recycled used for irrigation);
(ST) use light-weight cladding materials which react quickly to heat such as wood. Due to thermal lag effect of some materials, such as brick or concrete, store heat during daytime and release it at night when the UHI is most sensitive;
b. shading: minimise internal solar gain in summer
(ST) maximise North & South facing openings; high sun angles are easier to shade (recessed, overhang & vertical blinds in combination with solar control glazing);
c. air tightness & insulation
+14% beyond Part M requirements for new building and +7% for existing building (LEED-NC EA 1)
(ST) minimise infiltration to allow more controllable internal space and more efficient cooling system;
(ST) insulate to keep heat out in summer;

2. Roof: to follow LEED-NC SS 7.2
(ST) increase percentage of reflective surfaces (high albedo);
(ST) "Green roof can insulate against heat gain, absorb rainfall and provide useable outdoor space." (LCCP, 2005);
(ST) 50% of the roof covered with green roof or 75% of the roof covered with reflective surfaces
SRI > 29 for sloped roof > 2:12 & SRI > 78 for sloped roof < 2:12
or a combination of the above as: (area of SRI roof / 0.75) + (area green roof / 0.5) = roof area

7.1.3 Building systems & Anthropogenic heat source

Finally, heat and air pollution produced by human activities are considered. This part encourages the use of natural ventilation and daylighting.

1. Ventilation
(ST) favour natural ventilation in combination with exposed internal thermal mass (floor & ceiling); especially for high occupancy uses;
(ST) use adaptive techniques such as evaporative cooling to meet thermal comfort conditions;
(ST) increase floor to ceiling heights, this allows larger building deep under natural ventilation system and ease later addition of cooling mechanisms (chilled beam or ceiling with displacement ventilation);

2. Air conditioning
(ST) consider low energy cooling techniques such as free cooling for ventilation, reflective slab cooling, night cooling or evaporative cooling before specifying air conditioning system;
(ST) reduce cooling load by solar shading and improve the thermal insulation;
(ST) outlet to be located at a high point: above roof level;
(ST) combine with heat-recovery system or generate electricity from wasted heat;
(ST) powered by local renewable energy source such as solar energy which is most available when cooling is needed;
(ST) shift the peak of the anthropogenic heat released by utilizing the heat storage system;

3. Efficient building system and equipments: reduce casual heat gain
(ST) be category A or as energy efficient as practicable;
(ST) use as much renewable energy as possible;
(ST) introduce a series of control systems such as timers, photo-sensors or centralised over-ride controls with localised circuits;
(ST) monitor power consumed and hours run;
(ST) at borough level : utilize unused energy such as the exhaust heat from incineration plant or the waste heat from sewage plant;
(ST) at borough level : introduce high-performance district heating & cooling infrastructure;
(ST) reduce the temperature of exhaust air from building equipments ;

4. Transport
(ST) encourage cycle and pedestrian travel by providing storage and shower facilities.
(ST) green transport / travel plan

7.2 Weighting system

UHI checklist should be a flexible appraisal methodology; used throughout the life of the project: from the site selection to occupation. It also assesses existing development and generates building improvement proposals.

The use of UHI checklist upstream can ensure an integrated solution. As part of the planning process, it involves all disciplines which increases the opportunity for innovative solution. Used as a snapshot at different design stages, it monitors the performance encouraging Best Practice.

Each ST of the checklist defines an indicator. Like BREEAM, building's performances are rated against each indicator (1 or 0) and the overall score gives the UHI rating following the scale:

Pass > 20 Good > 30 Very good > 40 Excellent > 50

These ratings were chosen to "best judgement" from the CASBEE-HI case study results.

To follow CASBEE-HI model the mitigation strategies relate to the building and human scale and the planning envelop set the boundary of the assessment.

Following chapter VI, external building envelop and building systems. Each indicator score is weighted against three site conditions; defined by the density or floor area ratio (FR):

- low density, FR 1 < 100%.
- medium density, 100% < FR 2 < 300%;
- high density, FR 3 > 300%;

To follow an assessment of the case study results, these ratios have been reduced compared to the CASBEE-HI model to reflect London's densities. Most of the dwellings were under FR100% which determine the first step; and only the high rise were over FR300%; this set-up the third step. However the weightings should have the same sensitivity:

- low density site affected by 'site & layout';
- high density site affected by 'building systems'.

The surrounding conditions are also taken into consideration and refer to the following category:

- building sites next to large open space, waterfront, large park, etc (x 1.4);
- few open spaces around the building site (x 1.2).

The related coefficients determine the final rating.

The following table illustrates a draft of UHI project checklist.

Project Name (type)

Project address (surronding conditions & FR)

		Score	FR 1	FR 2	FR 3	TOTAL
1 Site & Layout		**13**	**2.60**	**1.30**	**0.50**	
SL 1	Wind: Reduce the ratio building height vs. street width	1				
SL 2	Wind: Create ventilation lanes between building by introducing low level vegetation	1				
SL 3	Wind: direct winds to leeward side using building height & geometry as well as interval	1				
SL 4	Wind: reduce buildings aspect ratio against prevailing wind direction in summer	1				
SL 5	External spaces: Introduce courtyard with vegetation and water feature	1				
SL 6	External spaces: 50% of the site hard landscape covered with reflective surfaces (SRI > 29)	1				
SL 7	External spaces: 50% of the site hard landscape covered with gravelled or permeable and porous paving	1				
SL 8	External spaces: maximise green space area which should be arranged down a slope and re-use water run off	1				
SL 9	External spaces: water features with minimal net water use and solar powered pumps to re-circulate water	1				
SL 10	External spaces: vegetation species adapted to seasonal rainfalls (UKCIP)	1				
SL 11	External spaces: maintenance strategy to include rainwater harvesting or grey-water recycling to irrigate gardens and	1				
SL 12	External spaces: 50% of pedestrian space shaded by trees, piloti, eaves or pergola in summer	1				
SL 13	External spaces: use deciduous planting	1				
2 External Building Envelop		**7**	**1.00**	**1.30**	**1.00**	
BE 1	Façade: 20% of cladding covered with reflective surfaces (SRI > 29)	1				
BE 2	Façade: introduce vertical gardens, balconies with planters or climbers, particularly on the South and West elevations	1				
BE 3	Façade: use light-weight cladding materials	1				
BE 4	Façade: maximise North & South facing openings	1				
BE 5	Façade: introduce shadding device and solar control glazing	1				
BE 6	Façade: insulation & air tightness, 14% beyond Part M requirements for new building & 7% for existing building	1				
BE 7	Roof: 50% of the roof covered with green roof or 75% with reflective surfaces or a combination of the two	1				
3 Building Systems & Antropogenic heat		**18**	**0.50**	**1.30**	**2.00**	
BS 1	Ventilation: natural ventilation in combination with expose internal thermal mass	1				
BS 2	Ventilation: use adaptive technique such as evaporative cooling to meet thermal comfort conditions	1				
BS 3	Ventilation: increase floor to ceiling heights for natural ventilation or later addition of cooling mechanisms	1				
BS 4	Air conditioning: consider low energy cooling techniques	1				
BS 5	Air conditioning: reduce cooling load by solar shading and improve the thermal insulation	1				
BS 6	Air conditioning: outlet to be located at a high point: above roof level	1				
BS 7	Air conditioning: combine with heat-recovery system or generate electricity from wasted heat;	1				
BS 8	Air conditioning: powered by local renewable enegy source such as solar energy	1				
BS 9	Air conditioning: shift the peak of the anthropogenic heat released by utilizing the heat storage system	1				
BS 10	Building system & equipments: category A or as energy efficient as practicable	1				
BS 11	Building system & equipments: use as much renewable energies as possible	1				
BS 12	Building system & equipments: use control system such as timer, photo-sensor or centralised over-right	1				
BS 13	Building system & equipments: monitor power consumed and hours run	1				
BS 14	Building system & equipments: utilize unused energy such as the exhaust heat from incineration plant	1				
BS 15	Building system & equipments: introduce high-performance district heating & cooling infrastructure	1				
BS 16	Building system & equipments: reduce the temperature of exhaust air from building equipments	1				
BS 17	Transport: encourage cycle and pedestrian travel by providing storage and shower facilities	1				
BS 18	Transport: provide a green transport plan	1				
Surronding conditions						
SC 1	Building site next to large open space, waterfront, park...					1.40
SC 2	Few open spaces around the building site					1.20
FINAL score						

Fig 7.01 UHI Project Checklist

7.3 Case studies

In this section the UHI Project Checklist will be tested by three case study categories: dwellings built before 1995, dwellings built after 1995 and offices built after 1995. The following examples are the same tested in chapter VI, CASBEE-HI modelling.

7.3.1 Dwellings built before 1995

The five developments are located near Hammersmith. Built before 1995 and of the Victorian area they have the following characteristics:

- A1: detached house FR1 & SC1 (Appendix 11)
- A2: semi-detached house FR1 & SC2
- A3: terrace house FR2 & SC2
- A4: purpose built flats FR2 & SC2
- A5: conversion flats & maisonette FR2 & SC2

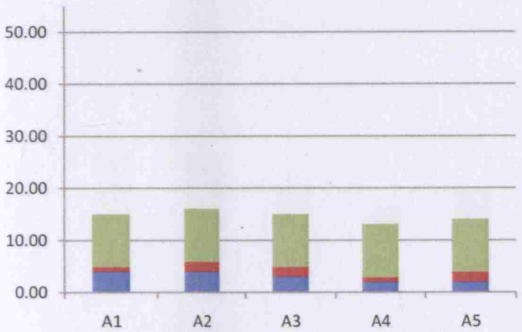


Fig 7.02 Score for all dwellings A1 to A5, per main category

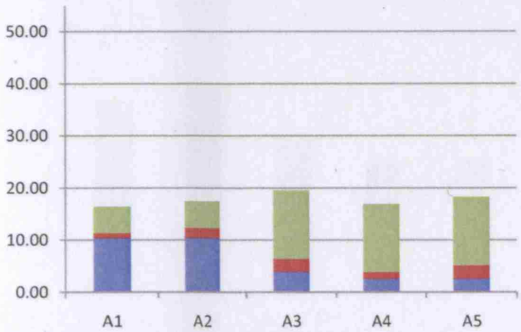


Fig 7.03 Score for all dwellings A1 to A5, with density weighting per main category

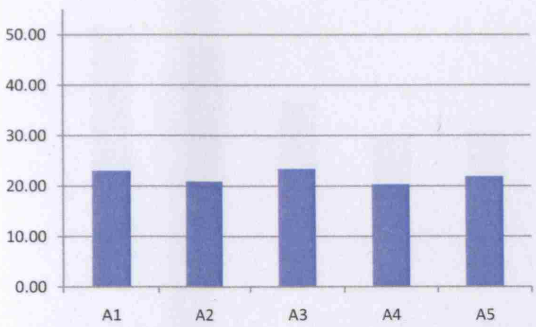


Fig 7.04 Final score for all dwellings A1 to A5, with density & surrounding conditions weighting per main category

The graph 7.04 shows UHI final predicted results which are between 20 & 23: all the dwellings achieve a low pass. The 'Building systems' are the same for all case studies: natural ventilation; which means that they scored the same against the primary indicators. Differences occur on the 'Site & layout' or the 'External envelop'.

A1 and A2 are in the low density category FR1, which gives more importance to 'Site & layout'. This is reflected in graph 7.03, after applying the density weighting its share rise from 25% to 60%. In examples A3, A4 and A5; medium density category (FR2) gives the same weighting to each indicator. As illustrated in graph 7.03 the scores rise proportionally as factor of 1.3.

The second weighting 'surrounding conditions' has a impact on A1 final score which is higher than A2 only in this last graph 7.04.

The terrace house scores the highest due to its landscape front and back gardens, its N-S orientation and its highly reflective facade. It is followed by the detached house which creates ventilation lanes and introduces low level vegetation.

Building systems & Antropogenic heat source
External Building Envelop
Site & Layout

7.3.2 Dwellings built after 1995

The following five recent developments are located across London and represent five dwelling typologies. Built after 1995 they have the following characteristics:

- B1: detached house FR1 & SC1 (Appendix 11)
- B2: semi-detached house FR1 & SC2
- B3: terrace house FR1 & SC2
- B4: purpose built flats FR3 & SC2
- B5: conversion flats & maisonette FR2 & SC2

UHI predicted results vary: B1 scores above 50 in the 'excellent' category; B2 scores a high 'very good' and finally B3, B4 & B5 score 'good' (Fig 7.07). Although naturally ventilated schemes, they vary on: their floor to ceiling heights, their use of energy efficient building system, equipments and control system. The case studies adopt very different 'Site & layout' strategies: while B2 achieves most of the requirements, B4 approach is poor as it only intends to maximise the built area ratio. In FR3 category, B4 'Building systems' play a key role in the final score: their share rise from 60 to 80% after applying the 'density' weighting (Fig 7.06).

As per A1 and A2, B1 scores higher than B2 due to the 'surrounding conditions' weighting.

Despite all the site constraints, the detached and semi-detached house attend to use the wind and the external features as an asset. The green roof and pounds only complement their geometry, playing with noise and privacy issues.

With regards to the purpose built flats, we could suggest some improvements, such as introducing vegetation and water features in the pedestrian space with irrigation system via rainwater harvesting or grey-water recycling. This will increase the final score by 3.6 points while improving the building system and introducing renewable energy will add 12 points. This will bring B4 to the 'very good' category.

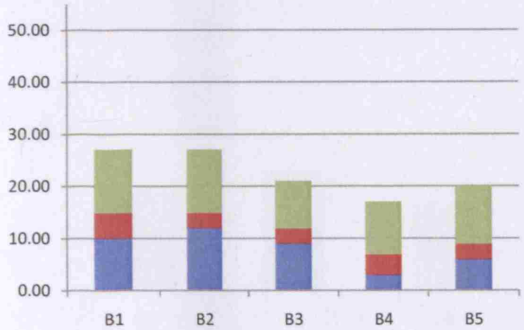


Fig 7.05 Score for all dwellings B1 to B5, per main category

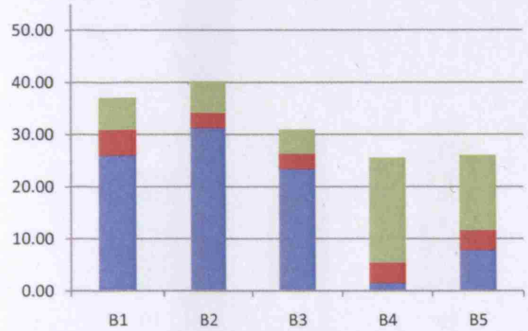


Fig 7.06 Score for all dwellings B1 to B5, with density weighting per main category

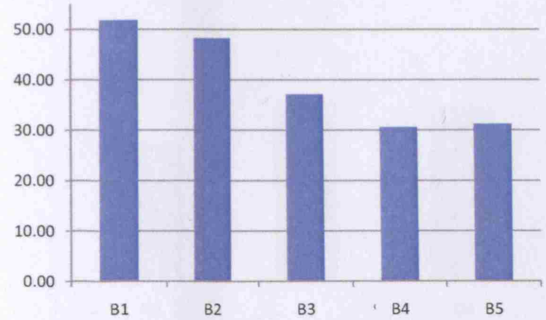


Fig 7.07 Final score for all dwellings B1 to B5, with density & surrounding conditions weighting per main category

Building systems & Antropogenic heat source
External Building Envelop
Site & Layout

7.3.3 Offices built after 1995

The following three recent developments are located across London and represent three offices typologies. Built after 1995 they present the following characteristics:

- B1: office tower FR3 & SC2 (Appendix 11)
- B2: office park FR2 & SC2
- B3: conversion office FR3 & SC2

The office results are average and vary between 'pass' and 'good' (Fig 7.10). This is surprising for Chiswick Park which achieved A with CASBEE-HI. Although the site integration strategy is excellent, the project could have included green walls, renewable technology or district heating/cooling. This would have added 5.2 points to the final score and reached the 'very good' category. Even if the office conversion shows a poor site strategy, its choice for natural ventilation and high density prove to be rewarding with 34.8 final score. Finally the tower scores average on all three main criteria. To obtain 'very good', this development should up-grade its building systems and include the following: adaptive cooling technique, AC outlet located at a high point, renewable energy source, heat storage system, etc.

In conclusion, we observe the following: to perform in this UHI checklist, the scope of measures used has to relate to the development's density and surrounding conditions; i.e. building services for dense area and site layout for low density projects.

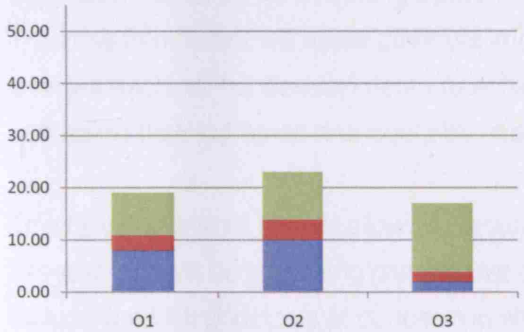


Fig 7.08 Score for all offices O1 to O3, per main category

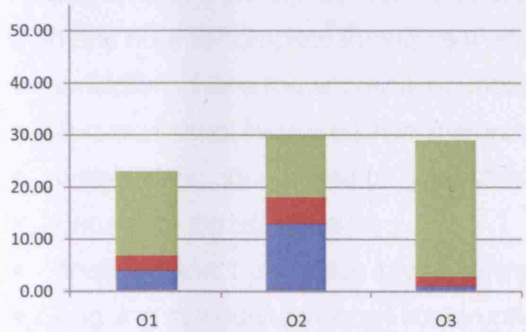


Fig 7.09 Score for all offices O1 to O3, with density weighting per main category

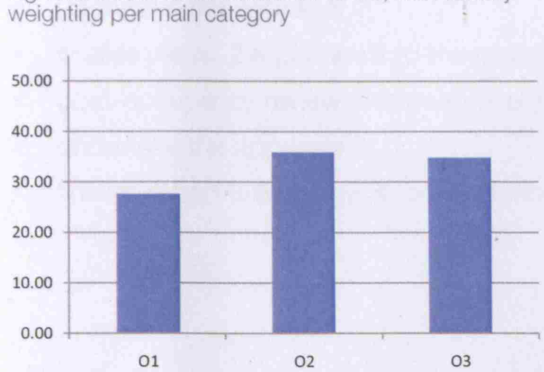


Fig 7.10 Final score for all offices O1 to O3, with density & surrounding conditions weighting per main category

Building systems & Antropogenic heat source
External Building Envelop
Site & Layout

7.4 Analysis

As London is adopting the principle of sustainable development, it will need to consider UHI effect in its policy and set some benchmarks. A framework or assessment tool needs to be in place in order to measure the success of the policy and the investment. This will require evidence in the form of quantitative measures; for example: the thermal comfort of residents in a new development through summer time will be assessed by a survey providing statistic views. In this example qualitative data is represented in quantitative form.

After analysing London's statutory framework and the current assessment tools, I have decided to create a new 'UHI checklist' for London. This tool will prioritise criteria to suit London's particular circumstances. It is based on LCCP guidance for its indicators, BREEAM for its form, CASBEE-HI the Japanese model for its weighting system.
The new framework will assist planners implementing Policy 4A.10 of the London Plan. They could set a target such as: 'all developments to achieve a minimum UHI level of 35'. This will help developers assessing their schemes and could be used as a marketing tool.

This UHI framework should allow the project to progress in a coherent and systematic way. The first assessment will be a learning platform for the planners and the design team, the following project will include the UHI principles at conception stage and there onwards the assessment should be fluid. Having in mind a project fast-track timescale, once in place the UHI assessment should not take more than one hour to complete through a workshop. The proposed appraisal process is as follows:

- induction: define the appraisal boundary and identify team members and stakeholders;
- first workshop: review each indicators with the relevant stakeholders at conception stage;
- collect data: documentation, workshop, site visit;
- undertake the appraisal 1;
- finalise report 1 and issue it for planning;
- ongoing monitoring through construction;
- undertake the appraisal 2;
- finalise report 2 and issue it to the planner at completion;
- post-occupancy review (minimum one year after completion);
- undertake the appraisal 3;
- finalise report 3 and issue it to the planner.

Why should we evaluate London's UHI by using this new checklist? The first advantage of this tool is to engage the evaluation process. At the present there is no agreed structure, hence the following problems rise:

- LCCP guidance looses coherence as no benchmarks are mentioned nor assessment strategies linking the design and planning process;
- the understanding of UHI effects is difficult as they are described in different ways;
- the collection of data only addresses part of the subject and cannot be linked together.

The proposed checklist clearly identifies the mitigation strategies and proposes an holistic approach.

As part of the analysis, we should point out other advantages of the UHI checklist:

- it identifies project's weaknesses and strengths;
- it helps developing alternative strategies;
- it could be used through the planning process, in public consultation or as a training tool;
- it captures the evolution of the project over time;
- it demonstrates to the stakeholder why investment is needed in specific areas: health, energy cost and water restriction.

On the other hand, one of its limitations could be the involvement of a team with varied skills rather than one individual.

To conclude, location and design could minimise the project's vulnerability to overheating.
For new schemes, the UHI assessment should start in early design stages, then the mitigation strategies will be most efficient and their costs relatively low. For existing developments, retrofitting buildings should reduce the running costs such as heating and cooling.

7.5 Summary

Decision-making for UHI mitigation strategies requires a framework within the planning process that is able to structure the issues. This chapter develops a new UHI checklist based on LCCP guidance, which recognises three levels of information:

- site & layout;
- external building envelop;
- building systems & anthropogenic heat source.

These suggest an integration of the key mitigation strategies. It aims to guide planners, designers, developers and decision-makers through the process of evaluating and understanding London's UHI. The checklist does not overcome all the issues directly but provides opportunities for collaboration between stakeholders.

As the investigation was based on current frameworks and assessment tools, it was not essential to set absolute targets. Although it is probable that the future planning directives will require the design team to demonstrate a mitigation strategy towards overheating in order to comply with NI 188.
In this case, this new checklist should be tested on 'live projects' to collect data and assess its efficiency. A sensitivity study should be developed in order to identify the mitigation strategies to prioritise. This will inform a new 'local heat wave plan' (MOL 2006) to manage overheating in summer. Finally the social, aesthetical and economical impact of London UHI checklist should be reviewed. These issues are outside the scope of this dissertation; nevertheless they should be addressed in the future.

VIII. Conclusion

This study has provided an overview of the causes and the consequences of the Urban Heat Island effects; positive phenomenon in winter, negative in summer. It has also introduced a new framework to assess the built environment. The design considerations highlighted by the dissertation include the following:

- building layout and design should encourage wind flow;
- maximise landscape garden areas by introducing reflective surfaces, water features, external shading and deciduous planting (Fig 8.01);
- green the external envelop and the roof or alternatively use reflective surfaces;
- introduce facade shading devices and solar control glazing;
- consider low energy cooling techniques such as natural ventilation with exposed thermal mass and night cooling or mixed-mode ventilation;
- reduce the building systems and equipment loads by introducing energy efficient systems, control and optimisation procedures, heat-recovery devices or generate electricity from wasted heat.

Mitigation strategies should not only apply to the built environment, we should also consider an action plan such as the 'Philadelphia's Heat wave Preparedness Plan' (MOL, 2006).
Finally, we do not know what will happen in the future, even with economic or climate forecast. We can only make reasonable assumptions based on past events and try to overcome the consequences. The UHI checklist will need to adapt to new technologies and to economical, social and political change. This study has provided a comprehensive structure with key indicators and raised issues for future research.

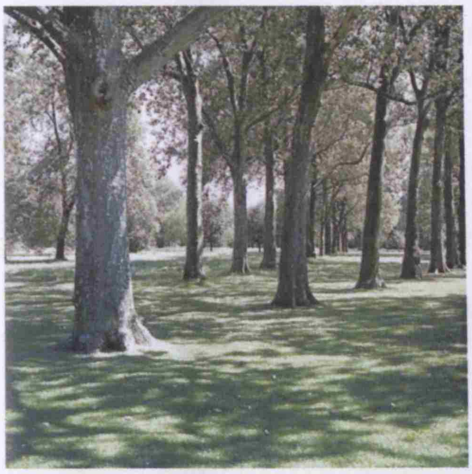


Fig 8.01 Kensington Gardens, London and Yorkville Park, Toronto (Czerniak & Hargreaves, 2007)

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Appendices

Appendix 1. London psychometric chart

Appendix 2. London's morphology

Appendix 3. London's demography

Appendix 4. Summary of the conversation with Paul Baker

Appendix 5. Building Regulations Checklist

Appendix 6. CASBEE for New Construction Tool-1

Appendix 7. CASBEE-HI

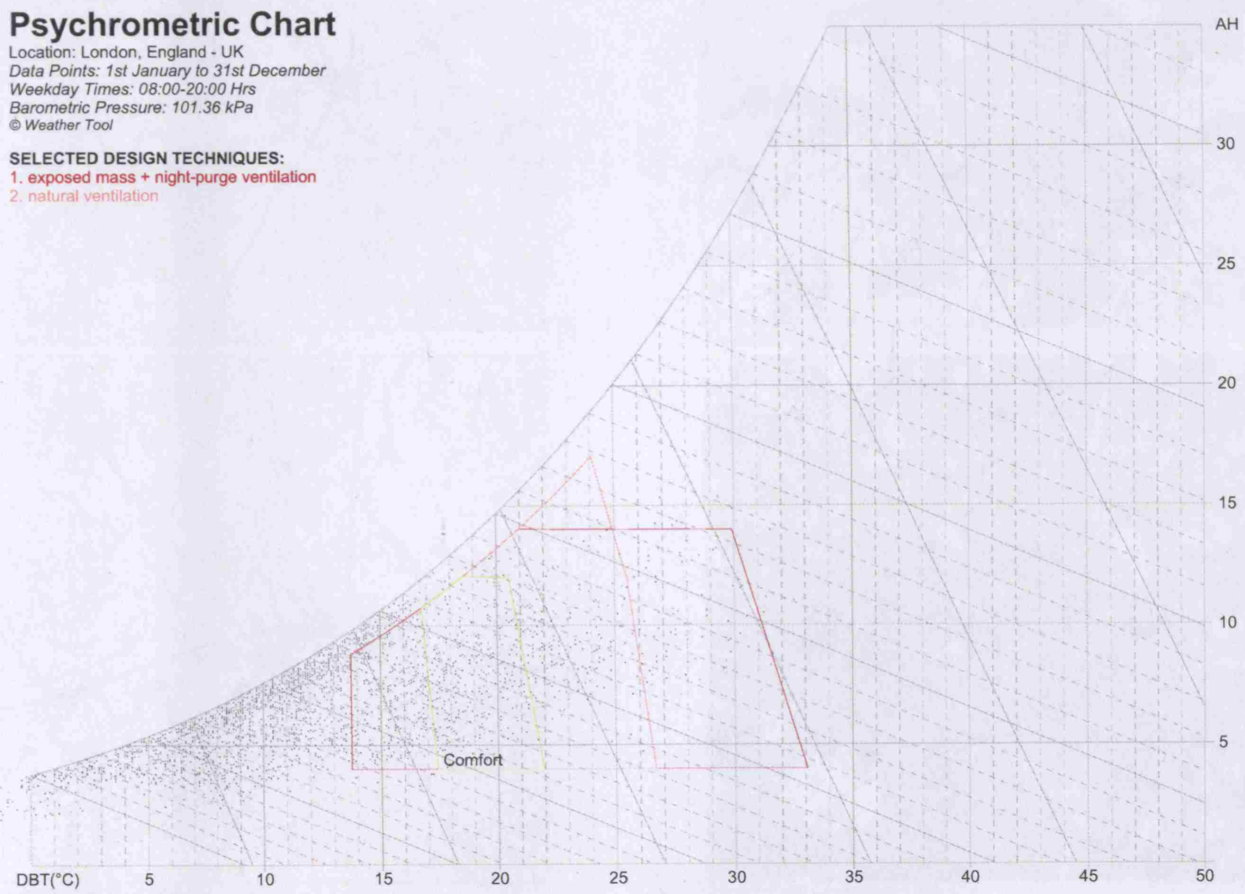
Appendix 8. Town and Country Planning (Use Classes) Order 1987 & NLUD Land Use Classification

Appendix 9. CASBEE-HI Score Sheet

Appendix 10. Business emissions rate in London

Appendix 11. UHI ckecklist Score Sheet

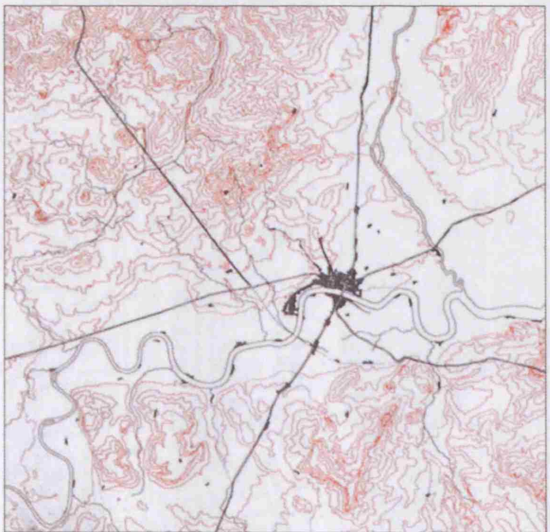
Appendix 1. London psychometric chart (source: weather tool, www.squ1.com)



Appendix 2. London's morphology

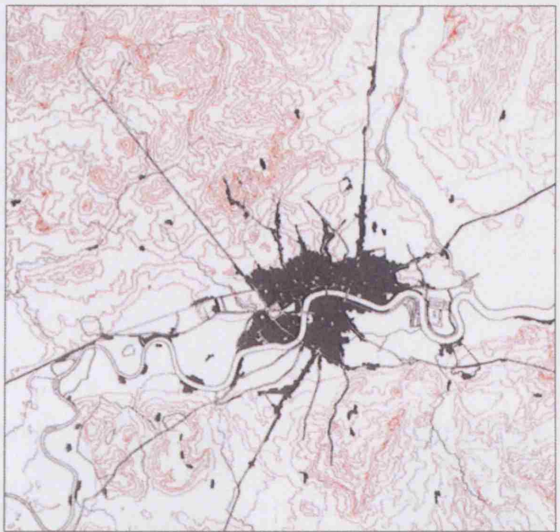
a. Fabric of London from the Roman time to the twentieth century (Jones & Woodward, 2000)

Roman London

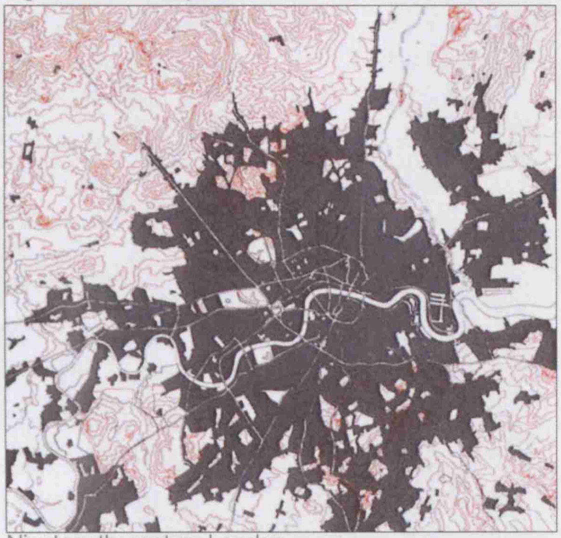


Medieval and Tutor London

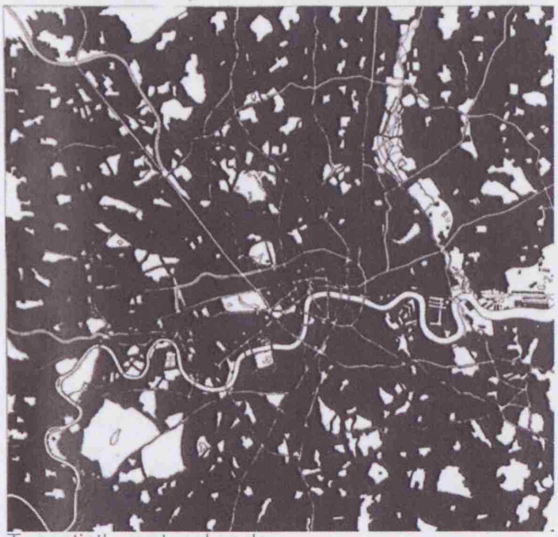
Seventeenth-century London



Eighteenth-century London

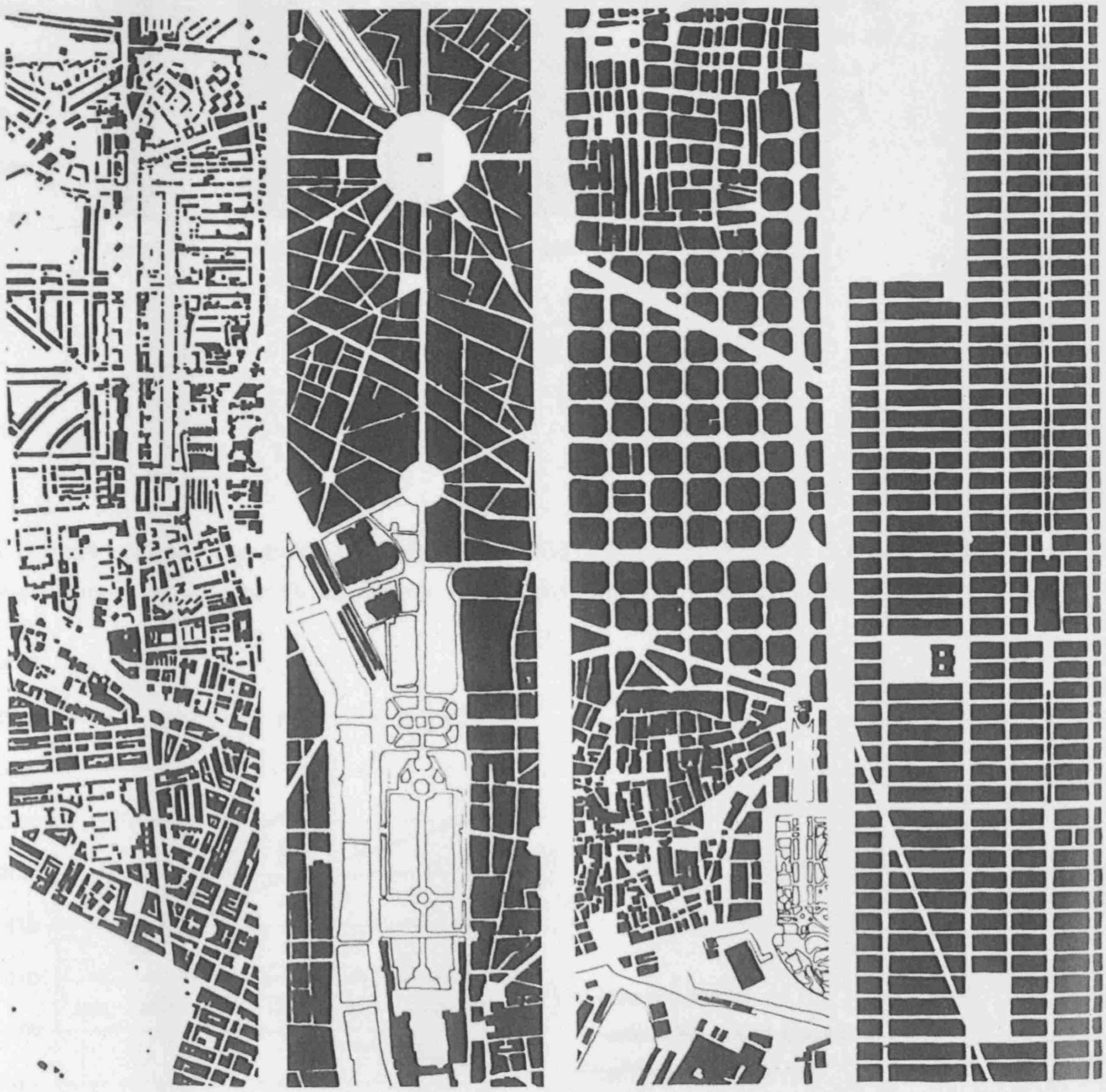


Nineteenth-century London



Tweentieth-century London

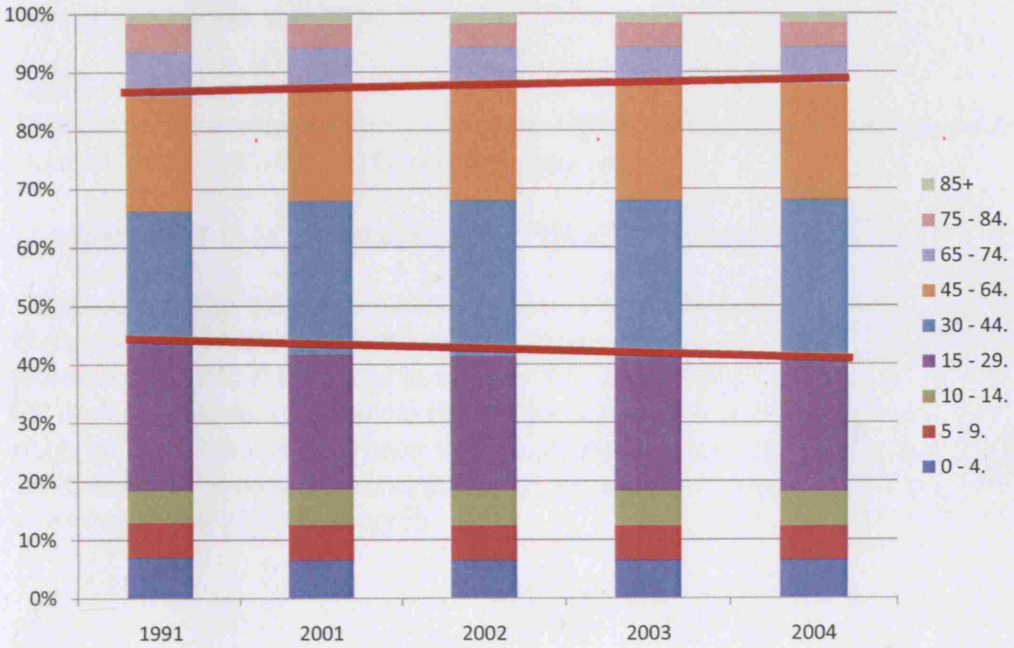
b. Fabric of four cities: London, Paris, Barcelona and Manhattan (Jones & Woodward, 2000)



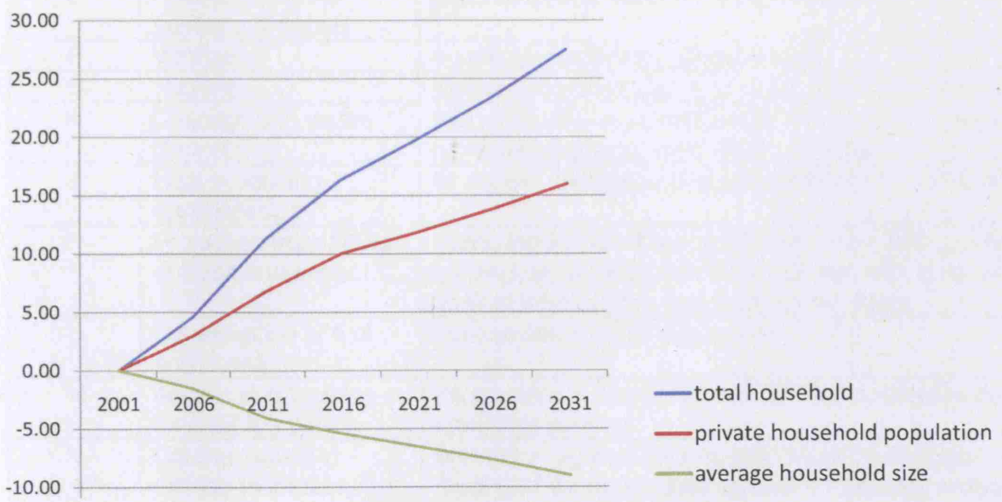
London Paris Barcelona Manhattan

Appendix 3. London's demography

a. Population by age groups 1991 to 2004 based on Bains B. Hay G.& Klodawski E. Greater London Demographic Review 2004, December 2005, p4 Table 2.



b. Greater London Household Summary 2001 to 2031; based on G. Hay & J. Hollis; Data Management and Analysis Group, Interim Household Projections, March 2006, p10 Table 3.



Appendix 4. Summary of the conversation with Paul Baker, Senior Environmental Policy & Projects Officer at Hammersmith & Fulham Borough Council.

Date: Thursday 3rd, July 2008

Name: Paul Baker
Title: Senior Environmental Policy & Projects Officer at Hammersmith & Fulham Borough Council
Contact: 020 8753 3431, paul.baker@lbhf.gov.uk

Question Asked: How he is implementing Policy 4A.10 of the London Plan?

PB views was that the wording of this Policy: 'should, strongly encourage'; make the review non-compulsory. Therefore overheating is usually overlooked during the planning assessment.
Moreover it is difficult to assess as no unify framework exist.
PB preferred option would be the introduction of a supplementary guidance including best practice options. This information will pass on through training and information support system such as the Creative Environmental Networks (CEN); an organisation frequently used by planners: www.cen.org.uk (Planner support)

Appendix 5. Building Regulations Checklist

Part		Requirements
A	Structure	loading, ground movement, disproportionate collapse
B	Fire safety	means of escape, internal fire spread (linings & structure), external fire spread, access and facilities for the fire services
C	Site preparation and resistance to moisture	preparation of site, dangerous & offensive substances, subsoil drainage, resistance to weather and ground moisture
D	Toxic substances	cavity insulation
E	Resistance to the passage of sound	airborne sound (walls & floors), impact sound
F	Ventilation	means of ventilation, condensation
G	Hygiene	sanitary conveniences & washing facilities, bathrooms, hot water storage
H	Drainage and waste disposal	foul water drainage, cesspools, septic tanks & settlements tanks, rainwater drainage, solid waste storage
J	Heat producing appliances	air supply, discharge pf products of combustion, protection of building
K	Protection from falling collision and impact	stairs, ladders & ramps, protection from falling, vehicle barriers and loading bays, protection from collision with open windows, protection against impact from and trapping by doors
L	Conservation of fuel and power	conservation of fuel and power
M	Access and facilities for disabled people	interpretation, access & use, sanitary conveniences, audience or spectator seating
N	Glazing, safety in relation to impact, opening and cleaning	protection against impact, manifestation of glazing, safe opening & closing of windows, safe access for cleaning windows

Appendix 6. CASBEE for New Construction Tool-1 (2004 Edition) www.ibec.or.jp

a. CASBEE Assessment Results Sheet

Comprehensive Assessment System for Building Environmental Efficiency

CASBEE for New Construction

CASBEE-NCe_2004v1.02

Assessment sheet of Execution Design Stage | Assessment date 05-Jun-04 | Assessor XXX | Date of approval 10-Jul-04 | Approved by XXX

(1) Building Outli *1

Building Name	XX building		
Building Type	Offices		
Location / Climate	XX city, XX pref.		Zone V
Area / Zone	Commercial Area		
Completion	Aug-03 Scheduled	Number of Floors	+XX F
Site Area	XXX m^2	Structure	RC
Construction Area	XXX m^2	Occupancy	XX persons
Gross Floor Area	XXX m^2	Annual Occupancy	XXX hrs/yr

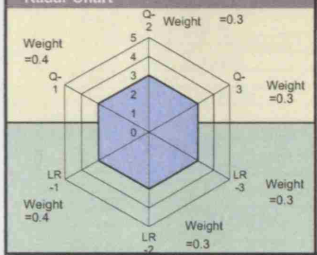
Appearance, views, etc.

Unprotect sheet when you paste pictures

(2) Results of Comprehensive Assessment for Building Environmental Efficiency *1*2

(2)-1 Building Environmental Quality & Performance and Load Reduction (Results by Category)

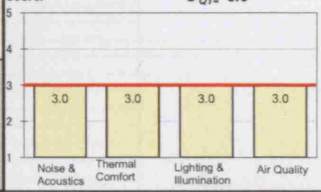
Radar Chart



Q. Building Environmental Quality & Performance

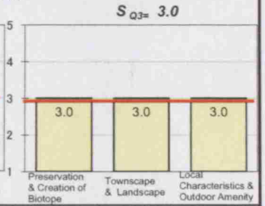
Score: $S_Q = 3.0$ *SQ = 0.4* SQ1 + 0.3 * SQ2 + 0.3 * SQ3

Q-1



Q-2

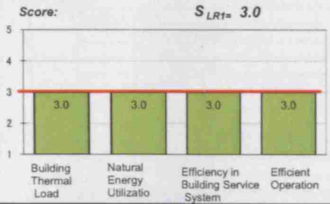
Q-3



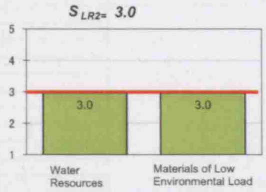
LR. Reduction of Building Environmental Loadings

Score: S_{LR} = 3.0 SLR = 0.4 * SLR1 + 0.3 * SLR2 + 0.3 * SLR3

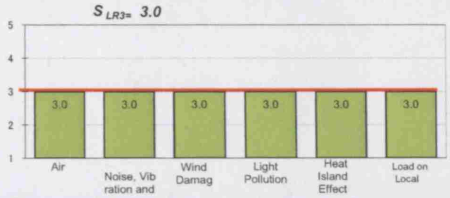
LR-1



LR-2

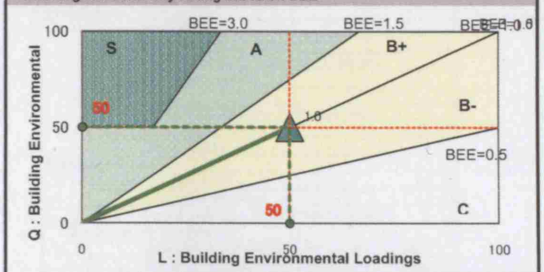


LR-3



(2)-2 BEE Building Environmental Efficiency

Building Sustainability Rating based on BEE



$$BEE = \frac{\text{Building Environmental Quality \& Performance Q}}{\text{Building Environmental Loadings L}}$$

$$= \frac{25 * (S_Q - 1)}{25 * (5 - S_{LR})} = \frac{50}{50} = 1.0$$

$Q = 25 * (S_Q - 1)$ *S_Q: Score of Q category

SQ = 0.4* SQ1 + 0.3 * SQ2 + 0.3 * SQ3

$L = 25 * (5 - S_{LR})$ *S_{LR}: Score of LR category

SLR = 0.4 * SLR1 + 0.3 * SLR2 + 0.3 * SLR3

(3) Important Assessment Items Excluded from Comprehensive Assessment for Building Environmental Efficiency *3

(3)-1 Quantitative Assessment Indicators for Typical Building Environmental Loadings

<Input when the detailed assessment is carried out at the Execution Design & Construction Completion Stage >

	Value / y / m^2		Value / person / h		Reduction / y / m2		Reduction Rate %
Energy consumption in building operation		MJ/y/m^2		MJ/person/h		MJ/y/m^2	0 %
CO_2 emission in building operation		kg-CO_2/y/m^2		kg-CO_2/person/h		kg-CO_2/y/m^2	
Water consumption		m^3/y/m^2		m^3/person/h		m^3/y/m^2	
Lifecycle CO_2 emission		kg-CO_2/y/m^2		kg-CO_2/person/h		kg-CO_2/y/m^2	
Lifecycle amount of waste disposal		t/y/m^2		t/person/h		t/y/m^2	
Lifecycle amount of resource		t/y/m^2		t/person/h		t/y/m^2	

(3)-2 Design Process Assessment

Concerned Items

Design Stage

1 Design by Accredited Professional

Construction Stage

2 Environmental Management Plan

Notes *1: Essential assessment results are displayed in (1) and (2).

*2: Site - selection - related assessments are not included. A standard building constructed on this site is given the score of 3."NA" denotes that the item is excluded from assessment.

*3: Assessment (3) is optional. If possible, it is recorded only in the execution design stage and the construction completion stage.

b. CASBEE Score Sheet 1/2

(4) Score Sheet — Execution Design Stage						
Concerned categories	Brief summary of Design for Environment	Entire Building and Common Properties: Score	Entire Building and Common Properties: weighting coefficients	Residential and Accomodation sections: Score	Residential and Accomodation sections: weighting coefficients	Total
Q Building Environmental Quality & Performance						**3.0**
Q-1 Indoor Environment			0.40			**3.0**
1 Noise & Acoustics		3.0	0.15	-	-	3.0
1.1 Noise		3.0	0.40	-	-	
1 Background noise		3.0	0.50	3.0	-	
2 Equipment noise		3.0	0.50	-	-	
1.2 Sound Insulation		3.0	0.40	-	-	
1 Sound Insulation of Openings		3.0	0.60	3.0	-	
2 Sound Insulation of Partition Walls		3.0	0.40	3.0	-	
3 Sound Insulation of Floor Slabs (light impact)		3.0	-	3.0	-	
4 Sound Insulation of Floor Slabs (heavy impact)		3.0	-	3.0	-	
1.3 Sound Absorption		3.0	0.20	3.0	-	
2 Thermal Comfort		3.0	0.35	-	-	3.0
2.1 Room Temperature Control		3.0	0.50	-	-	
1 Room Temperature Setting		3.0	0.30	3.0	-	
2 Variable Loads & Following-up Control		3.0	-	-	-	
3 Perimeter Performance		3.0	0.20	3.0	-	
4 Zoned Control		3.0	0.30	-	-	
5 Temperature & Humidity Control		3.0	0.10	3.0	-	
6 Individual Control		3.0	-	-	-	
7 Allowance for After-hours Air Conditioning		3.0	0.10	-	-	
8 Monitoring Systems		3.0	-	-	-	
2.2 Humidity Control		3.0	0.20	3.0	-	
2.3 Type of Air Conditioning System		3.0	0.30	3.0	-	
3 Lighting & Illumination		3.0	0.25	-	-	3.0
3.1 Daylighting		3.0	0.30	-	-	
1 Daylight Factor		3.0	0.60	3.0	-	
2 Openings by Orientation		3.0	-	-	-	
3 Daylight Devices		3.0	0.40	3.0	-	
3.2 Anti-glare Measures		3.0	0.30	-	-	
1 Glare from light fixtures		3.0	0.40	3.0	-	
2 Daylight control		3.0	0.60	3.0	-	
3.3 Illuminance Level		3.0	0.15	-	-	
1 Illuminance		3.0	0.70	3.0	-	
2 Uniformity Ratio of Illuminance		3.0	0.30	3.0	-	
3.4 Lighting Controllability		3.0	0.25	3.0	-	
4 Air Quality		3.0	0.25	-	-	3.0
4.1 Source Control		3.0	0.50	-	-	
1 Chemical Pollutants		3.0	0.25	3.0	-	
2 Mineral Fiber		3.0	0.25	3.0	-	
3 Mites, Mold etc.		3.0	0.25	3.0	-	
4 Legionella		3.0	0.25	3.0	-	
4.2 Ventilation		3.0	0.30	-	-	
1 Ventilation Rate		3.0	0.25	3.0	-	
2 Natural Ventilation Performance		3.0	0.25	3.0	-	
3 Consideration for Outside Air Intake		3.0	0.25	3.0	-	
4 Air Supply Planning		3.0	0.25	3.0	-	
4.3 Operation Plan		3.0	0.20	-	-	
1 CO_2 Monitoring		3.0	0.50	-	-	
2 Control of Smoking		3.0	0.50	-	-	
Q-2 Quality of Service			0.30			**3.0**
1 Service Ability		3.0	0.40	-	-	3.0
1.1 Functionality & Usability		3.0	0.60	-	-	
1 Provision of Space & Storage		3.0	0.33	3.0	-	
2 Adaptation of Building & Services to IT innovation		3.0	0.33	-	-	
3 Barrier-free Planning		3.0	0.33	-	-	
1.2 Amenity		3.0	0.40	-	-	
1 Perceived Spaciousness & Access to View		3.0	0.33	3.0	-	
2 Space for Refreshment		3.0	0.33	-	-	
3 Décor Planning		3.0	0.33	3.0	-	
2 Durability & Reliability		3.0	0.31	-	-	3.0
2.1 Earthquake Resistance		3.0	0.48	-	-	
1 Earthquake-resistance		3.0	0.80	-	-	
2 Seismic Isolation & Vibration Damping Systems		3.0	0.20	-	-	
2.2 Service Life of Components		3.0	0.33	-	-	
1 Necessary Refurbishment Interval for Exterior Finishes		3.0	0.29	-	-	
2 Necessary Renewal Interval for Main Interior Finishes		3.0	0.12	-	-	
3 Necessary Renewal Interval for Plumbing & Wiring Materials		3.0	0.29	-	-	
4 Necessary Renewal Interval for Major Equipment & Services		3.0	0.29	-	-	
2.3 Reliability		3.0	0.19	-	-	
1 HVAC System		3.0	0.20	-	-	
2 Water Supply & Drainage		3.0	0.20	-	-	
3 Electrical Equipment		3.0	0.20	-	-	
4 Support Method of Machines & Ducts		3.0	0.20	-	-	
5 Communications & IT equipment		3.0	0.20	-	-	
3 Flexibility & Adaptability		3.0	0.29	-	-	3.0
3.1 Spatial Margin		3.0	0.31	-	-	
1 Allowance for Story Height		3.0	0.60	3.0	-	
2 Adaptability of Floor Layout		3.0	0.40	3.0	-	
3.2 Floor Load Margin		3.0	0.31	3.0	-	
3.3 Adaptability of Facilities		3.0	0.38	-	-	
1 Ease of Air Conditioning Duct Renewal		3.0	0.17	-	-	
2 Ease of Water Supply & Drain Pipe Renewal		3.0	0.17	-	-	
3 Ease of Electrical Wiring Renewal		3.0	0.11	-	-	
4 Ease of Communications Cable Renewal		3.0	0.11	-	-	
5 Ease of Equipment Renewal		3.0	0.22	-	-	
6 Provision of Backup Space		3.0	0.22	-	-	
Q-3 Outdoor Environment on Site			0.30			**3.0**
1 Preservation & Creation of Biotope		3.0	0.30	-	-	3.0
2 Townscape & Landscape		3.0	0.40	-	-	3.0
3 Local Characteristics & Outdoor Amenity		3.0	0.30	-	-	3.0
3.1 Attention to Local Character & Improvement of Comfort		3.0	0.50	-	-	
3.2 Improvement of the Thermal Environment on Site		3.0	0.50	-	-	

b. CASBEE Score Sheet 2/2

LR Reduction of Building Environmental Loadings			-			**3.0**
LR-1 Energy			**0.40**			**3.0**
1 Building Thermal Load		**3.0**	0.30	-	-	**3.0**
2 Natural Energy Utilization		**3.0**	0.20	-	-	**3.0**
2.1 Direct Use of Natural Energy		-	-	-	-	
2.2 Converted Use of Renewable Energy		3.0	-	-	-	
3 Efficiency in Building Service System		**3.0**	0.30	-	-	**3.0**
4 Efficient Operation		**3.0**	0.20	-	-	**3.0**
4.1 Monitoring		**3.0**	0.50	-	-	
4.2 Operational Management System		**3.0**	0.50	-	-	
LR-2 Resources & Materials			**0.30**			**3.0**
1 Water Resources		**3.0**	0.15	-	-	**3.0**
1.1 Water Saving		**3.0**	0.40	-	-	
1.2 Rainwater & Gray Water		**3.0**	0.60	-	-	
1 Rainwater Use Systems		3.0	0.67	-	-	
2 Gray Water Reuse System		3.0	0.33	-	-	
2 Materials of Low Environmental Load		**3.0**	0.85	-	-	**3.0**
2.1 Recycled Materials		**3.0**	0.35	-	-	
1 Reuse Efficiency of Materials Used in Structure		3.0	0.67	-	-	
2 Reuse Efficiency of Non-structural Materials		3.0	0.33	-	-	
2.2 Timber from Sustainable Forestry		**3.0**	0.04	-	-	
2.3 Materials with Low Health Risks		**3.0**	0.08	-	-	
2.4 Reuse of Existing Building Skeleton etc.		**3.0**	0.18	-	-	
2.5 Reusability of Components & Materials		**3.0**	0.18	-	-	
2.6 Use of CFCs & Halons		**3.0**	0.18	-	-	
1 Fire Retardant		3.0	0.33	-	-	
2 Insulation Materials		3.0	0.33	-	-	
3 Refrigerants		3.0	0.33	-	-	
LR-3 Off-site Environment			**0.30**			**3.0**
1 Air Pollution		**3.0**	0.15	-	-	**3.0**
2 Noise, Vibration & Odor		**3.0**	0.15	-	-	**3.0**
2.1 Noise & Vibration		**3.0**	0.50	-	-	
2.2 Odors		**3.0**	0.50	-	-	
3 Wind Damage & Sunlight Obstruction		**3.0**	0.15	-	-	**3.0**
4 Light Pollution		**3.0**	0.10	-	-	**3.0**
5 Heat island effect		**3.0**	0.30	-	-	**3.0**
6 Load on Local Infrastructure		**3.0**	0.15	-	-	**3.0**

■ LR-1 Score book for each building type		Offices	-	-	-	Overall score on pro-rata area
		15000 m²	-	-	-	
1	**Building Thermal Load**	**3.0**	-	-	-	**3.0**
3 Efficiency in Building Service System	**Assessment by ERR**	**3.0**	-	-	-	**3.0**
	Assessment by means other than ERR	-	-	-	-	
3.1	HVAC System	3.0	-	-	-	-
3.2	Ventilation System	3.0	-	-	-	-
3.3	Lighting System	3.0	-	-	-	-
3.4	Hot Water Supply System	3.0	-	-	-	-
3.5	Elevators	3.0	-	-	-	-

Appendix 7. CASBEE-HI, www.ibec.or.jp & Mochida 2006

a. CASBEE-HI Score Sheet

Categories					Summary design	Sub-Score	Score	weighting coefficients 200	weighting coefficients 400	weighting coefficients 600	TOTAL
1 Urban Ventilation											
	Q1	Improvethe thermal environment by ventilating the pedestrian space	Q1.1	Take wind condition into consideration in the building arrangement planning and building geometry design		3.00	3.00	0.35	0.32	0.30	XX
			Q1.2	Create ventilation lanes by providing green spaces(Lawns, grassland, shrubs), but without objects such as tall trees that may block the pedestrian spaces from the wind flow		3.00					
	L1	Reduce the thermal effect on outside of the building siteby introducing airflows to the leeward	L1.1	Direct winds to leeward side through proper arrangement of buildings		3.00	3.00	0.22	0.19	0.15	XX
			L1.2	Reduce the aspect ratio of buildings against prevailing wind direction in summer		3.00					
			L1.3	Direct winds to leeward of building using the height and geometry of building as well as buildings interval		3.00					
2 Shading											
	Q2	Improve the thermal environment in pedestrian space by shading	Q2.1	Create shades by trees, piloti, eaves and pergola in the pedestrian space		3.00	3.00	0.23	0.21	0.20	XX
	L2	Reduce the thermal effect on outside of the building site by shading	L2.1	Make the shades by trees,piloti, eaves and pergolas in the building site		3.00	3.00	0.21	0.18	0.15	XX
3 Ground surface covering materials											
	Q3	Improve the thermal environment in pedestrian space using green elements and water body	Q3.1	Reduce the ground surface temperature by providing green elements and water body		3.00	3.00	0.17	0.16	0.15	XX
			Q3.2	Reduce asphalt-paved area within the building site		3.00					
	L3	Reduce the thermal effect on buildingon outside of the building site by appropriate ground cover materials	L3.1	Use ground cover materials with high permeability, high solar reflectance, etc.		3.00	3.00	0.21	0.18	0.15	XX
4 Building materials											
	Q4	Improve the thermal environment in the pedestrian space by greening	Q4.1	Greening the exterior wall surface of building, particularly on the south andwest walls which receive high solar radiation		3.00	3.00	0.17	0.16	0.15	XX
			Q4.2	Greening the rooftop that is accessible by people		3.00					
	L4	Reduce the thermal effect on outside of the building site by considering the thermal property of building materials	L4.1	Reduce heat flux into the building by greening the rooftop, or using high solar reflectance and low emittanceof long wave radiation roof covering materials		3.00	3.00	0.22	0.18	0.15	XX
			L4.2	Reduce heat flux into the building by greening the exterior walls of building, or using high solar reflectance and low emittanceof long wave radiation wall covering materials		3.00					
5 Anthropogenic heat releases from building equipments											
	Q5	Improve the thermal environment in pedestrian space by considering the locations of anthropogenic heat released from building	Q5.1	Emit the anthropogenic heat from air-conditioning system at a higher point		3.00	3.00	0.08	0.15	0.20	XX
			Q5.2	Emit high temperature waste heat from combustion equipment at a high point		3.00					
	L5	Reduce the amount of anthropogenic heat releases to the atmosphere	L5.1	Reduce the amount of anthropogenic heat releases to the atmosphere by preventing heat loss through outer walls and windows, as well as improving the energy efficiency of air-conditioning system		3.00	3.00	0.14	0.27	0.40	XX
				a) Reduce cooling load of air-conditioning system by solar shading and improve the thermal insulation property of building		3.00					
				b) Improve the efficiency of equipment systemsIntroduce energy-saving measures for air-conditioning ventilation, lighting and elevator systems		3.00					
				c) Utilize the natural energy #natural ventilation #daylight		3.00					
				d) Utilize the unused energy #exhaust heat from incineration plant #waste heat from sewage plant #seawater, river water and groundwater		3.00					
				e) Introduce high-performance infrastructuredistrict cooling and heating		3.00					
			L5.2	Reduce the temperature of exhaust air from building equipments		3.00					
			L5.3	Shift the peak of the anthropogenic heat released from the air-conditioning system by utilizing the heat storagingsystem, etc		3.00					

b. CASBEE-HI Assessment Results Sheet

CASBEE-HI ヒートアイランド現象緩和に関する建築物総合環境性能評価システム **評 価 結 果**

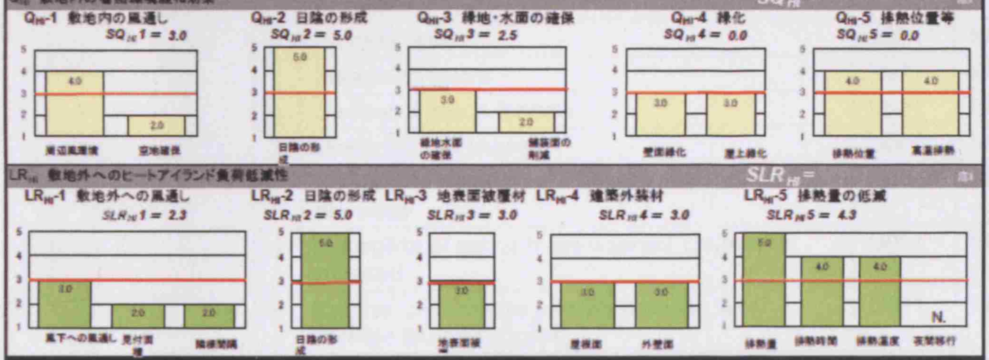
■使用評価マニュアル: CASBEE-HI (2006年版)
■使用評価ソフト: CASBEE-HI_2006(v1.0)

作成日 2006年4月24日 作成者 ○○○ 確認日 2006年4月24日 確認者 ○○○

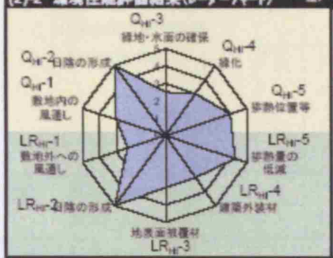
(1) 建築物概要

建物名称	モデルビルXX	敷地面積	3,150 ㎡	
建物用途		建築面積	1,950 ㎡	
建設地	東京都	建蔽率	61.9 %	外観パース等
気候区分		延床面積	15,600 ㎡	図を貼り付けるときは
地域・地区	商業地域、防火地域	容積率	495.2 %	シートの保護を解除してください
竣工年	2008年4月 0.0	階数	地上20階、地下1階	
法定容積率	600 %	構造	S+SRC造	
立地条件	①空地の少ない市街地等	平均居住人員	400 人	
		年間使用時間	2,300 時間/年	

(2)-1 環境性能評価結果 (バーチャート)

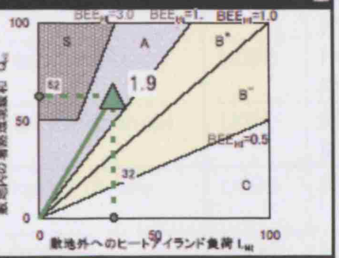


(2)-2 環境性能評価結果(レーダーチャート)



(2)-3 環境性能効率 BEE_{HI}

$$BEE_{HI} = \frac{\text{敷地内の暑熱環境緩和 } Q_{HI}}{\text{敷地外へのヒートアイランド負荷 } L_{HI}} = \frac{25 \times (SQ_{HI} - 1)}{25 \times (5 - SLR_{HI})} = \frac{62.3}{32.2} = 1.9$$



(3) 計画上の配慮事項

評価分野	中項目		小項目	計画上の配慮事項 記入欄
Q_{HI}:敷地内の暑熱環境緩和効果	Q_{HI}-1 敷地内の風通し	①	敷地周辺の風の状況を把握し、敷地内の歩行者空間等へ風を導く建築物の配置・形態計画とする	
		②	芝生・草地・低木等の緑地や通路等の空地を設けることにより、風の通り道を確保する	
	Q_{HI}-2 日陰の形成	①	中・高木の緑地やピロティ、庇、パーゴラ等を設けることにより、日陰の形成に努める	
	Q_{HI}-3 緑地・水面の確保	①	芝生・草地・低木等の緑地や水面を確保することにより、地表面温度や地表面近傍の気温等の上昇を抑制する	
		②	敷地内の舗装面積を小さくするよう努める	
	Q_{HI}-4 緑化	①	外壁面の緑化に努める	
		②	屋上(人が出入りできる部分)の緑化に努める	
	Q_{HI}-5 排熱位置等	①	建築設備(空調設備)に伴う排熱は、建築物の高い位置からの放出に努める	
		②	建築設備(燃焼設備)に伴う高温排熱は、建築物の高い位置からの放出に努める	
LR_{HI}:敷地外へのヒートアイランド負荷低減性	LR_{HI}-1 敷地外への風通し	①	建築物の配置・形態計画に当たっては、風下となる地域への風の通り道を遮らない	
		②	夏期の卓越風向に対する建築物の見付け面積を小さくする	
		③	風を遮らないよう、建築物の高さ、形状、建築物間の隣棟間隔等を勘案する	
	LR_{HI}-2 日陰の形成	①	中・高木の緑地やピロティ、庇、パーゴラ等を設けることにより、敷地内の日陰の形成に努める	
	LR_{HI}-3 地表面被覆材	①	保水性・透水性が高い被覆材、または、日射反射率の高い被覆材を選定するよう努める	
	LR_{HI}-4 建築外装材	①	屋根面の緑化に努める、または日射反射率、長波放射率の高い屋根材を選定することにより、建築物の入熱量を抑制する	
		②	外壁面の緑化に努める、または、日射反射率、長波放射率の高い外壁材料を選定するよう努める	
	LR_{HI}-5 排熱量の低減	①	建築物の外壁・窓等を通しての熱の損失の防止及び空気調和設備等に係るエネルギーの効率的利用のための措置を講ずることにより、大気への排熱量を低減する	
		②	建築設備に伴う排熱は、低温排熱にすること等により、気温上昇の抑制に努める	
		③	排熱のピークシフトをはかる	

Surffix HI: Heat Island Relaxation
凡例 Q: Quality L: Load LR: Load Reduction SQ: Score of Q category SLR: Score of LR category BEE: Building Environmental Efficiency
備考 注1: 当該建築物における標準的な設計の得点が3点。NAは評価対象外とした項目を示す。敷地選定に関わる評価は対象外。
注2: Q_{HI}は、敷地内の暑熱環境緩和効果(Q_{HI})のスコアSQ(Q_{HI}-1、Q_{HI}-2、Q_{HI}-3のスコアにそれぞれの重み係数を乗じた合計値)から算定。
L_{HI}は、敷地外へのヒートアイランド負荷低減性(LR_{HI})のスコアSLR(LR_{HI}-1、LR_{HI}-2、LR_{HI}-3のスコアにそれぞれの重み係数を乗じた合計値)から算定。

Appendix 8. Town and Country Planning (Use Classes) Order 1987 & NLUD Land Use Classification

http://www.planningportal.gov.uk/england/genpub/en/1011888237913.html

http://www.communities.gov.uk/publications/planningandbuilding/nationallanduse

a. Schedule 1/2

Use Classes Order				**NLUD land use classification**	
Class		**Class Description**		**Code**	**Group Name**
A1	**Shops**	a	Sale of goods (other than hot food)	U091	Shops
		b	Post office	U091	Shops
		c	Travel and ticket agencies	U091	Shops
		d	Sale of cold food for consumption off the premises	U091	Shops
		e	Hairdressers	U091	Shops
		f	Funeral directors	U091	Shops
		g	Display of goods for sale	U091	Shops
		h	Domestic hire shops	U091	Shops
		i	Washing or cleaning of clothes or fabrics on the premises	U091	Shops
		j	Reception of goods to be washed, cleaned or repaired	U091	Shops
		k	Internet café (where primary purpose is to provide Internet access)	U091	Shops
A2	**Financial and professional services**	a	Financial services (banks and building societies)	U092	Financial and professional services
		b	Professional services (excluding health and medical services)	U092	Financial and professional services
		c	Other services (including use as a betting shop) appropriate in a shopping area	U092	Financial and professional services
A3	**Restaurants and cafes**		Sale of food and drink for consumption on the premises	U093	Restaurants and cafes
A4	**Drinking establishments**		Public house, wine-bar or other drinking establishment	U094	Public houses and bars
A5	**Hot food takeaways**		Sale of hot food for consumption off the premises	U091	Shops
B1	**Business**	a	Offices other than financial and professional services providing for the visiting members of the public	U102	Offices
		b	Research and development	U102	Offices
		c	Other industrial processes appropriate in a residential area	U101	Manufacturing
B2	**General industrial**		General industry, not within B1	U101	Manufacturing
B8	**Storage or distribution**	a	Storage centre [2]	U103	Storage
		b	Distribution centre [2]	U104	Wholesale distribution
C1	**Hotels**		Hotels, boarding and guest houses, provided that care is not provided	U072	Hotels, boarding and guest houses
C2	**Residential institutions**		Residential accommodation for provision of care; residential schools and colleges and training centres; hospitals and nursing homes	U073	Residential institutions
C3	**Dwelling houses**		Dwelling houses for individuals, families and up to six individuals living as a single household	U071	Dwellings

b. Schedule 2/2

Use Classes Order				NLUD land use classification	
Class		**Class Description**		**Code**	**Group Name**
D1	**Non-residential institutions**	a	Medical or health services	U081	Medical and health care services
		b	Crèche, day nursery or day centre	U084	Community services
		c	Educational establishment	U083	Education
		d	Art gallery	U043	Libraries, museums and galleries
		e	Museum	U043	Libraries, museums and galleries
		f	Public library or public reading room	U043	Libraries, museums and galleries
		g	Public hall or exhibition hall	U043	Libraries, museums and galleries
		h	Public worship or religious instruction	U082	Places of worship
D2	**Assembly and leisure**	a	Cinema	U042	Amusement and show places
		b	Concert hall	U042	Amusement and show places
		c	Bingo hall or casino	U042	Amusement and show places
		d	Dance hall	U042	Amusement and show places
		e	Swimming bath, skating rink, gymnasium or area for other indoor sports [3]	U0441	Indoor sports facilities
		f	Outdoor sports areas and arenas [3]	U0442	Outdoor sports facilities
SG	**Sui Generis**	a	Theatre	U042	Amusement and show places
		b	Amusement arcade or centre, or a funfair	U042	Amusement and show places
		c	Launderette	U091	Shops
		d	Sale of fuel for motor vehicles	U091	Shops
		e	Sale or display for sale of motor vehicles	U091	Shops
SG	**Sui Generis**	f	Taxi business or business for the hire of motor vehicles	U091	Shops
		g	Scrap yard, or a yard for the storage or distribution of minerals or the breaking of motor vehicles	U104	Wholesale distribution
		h	Work registerable under the Alkali etc. Works Regulation Act 1906	U101	Manufacturing
		i	Hostels	U073	Residential institutions
		j	Waste disposal installation for the incineration, chemical treatment or landfill of waste	U063	Refuse disposal
		k	Retail warehouse club being a retail club where goods are sold, or displayed for sale, only to persons who are members of that club	U091	Shops
		l	Night-club	U042	Amusement and show places

Appendix 9. CASBEE-HI Score Sheet

a. Dwelling A1

Categories					Summary design	Sub-Score	Score	weighting coefficients 200	TOTAL
1 Urban Ventilation									
	Q1	Improvethe thermal environment by ventilating the pedestrian space	Q1.1	Take wind condition into consideration in the building arrangement planning and building geometry design		2.00	1.50	0.37	**0.56**
			Q1.2	Create ventilation lanes by providing green spaces(Lawns, grassland, shrubs), but without objects such as tall trees that may block the pedestrian spaces from the wind flow		1.00			
	L1	Reduce the thermal effect on outside of the building siteby introducing airflows to the leeward	L1.1	Direct winds to leeward side through proper arrangement of buildings		3.00	3.00	0.24	**0.72**
			L1.2	Reduce the aspect ratio of buildings against prevailing wind direction in summer		3.00			
			L1.3	Direct winds to leeward of building using the height and geometry of building as well as buildings interval		3.00			
2 Shading									
	Q2	Improve the thermal environment in pedestrian space by shading	Q2.1	Create shades by trees, piloti, eaves and pergola in the pedestrian space			1.00	0.22	**0.22**
	L2	Reduce the thermal effect on outside of the building site by shading	L2.1	Make the shades by trees,piloti, eaves and pergolas in the building site			1.00	0.21	**0.21**
3 Ground surface covering materials									
	Q3	Improve the thermal environment in pedestrian space using green elements and water body	Q3.1	Reduce the ground surface temperature by providing green elements and water body		2.00	3.00	0.17	**0.51**
			Q3.2	Reduce asphalt-paved area within the building site		4.00			
	L3	Reduce the thermal effect on buildingon outside of the building site by appropriate ground cover materials	L3.1	Use ground cover materials with high permeability, high solar reflectance, etc.			3.00	0.20	**0.60**
4 Building materials									
	Q4	Improve the thermal environment in the pedestrian space by greening	Q4.1	Greening the exterior wall surface of building, particularly on the south andwest walls which receive high solar radiation		2.00	1.00	0.16	**0.16**
			Q4.2	Greening the rooftop that is accessible by people		0.00			
	L4	Reduce the thermal effect on outside of the building site by considering the thermal property of building materials	L4.1	Reduce heat flux into the building by greening the rooftop, or using high solar reflectance and low emittanceof long wave radiation roof covering materials		1.00	1.00	0.22	**0.22**
			L4.2	Reduce heat flux into the building by greening the exterior walls of building, or using high solar reflectance and low emittanceof long wave radiation wall covering materials		1.00			
5 Anthropogenic heat releases from building equipments									
	Q5	Improve the thermal environment in pedestrian space by considering the locations of anthropogenic heat released from building	Q5.1	Emit the anthropogenic heat from air-conditioning system at a higher point	n/a	3.00	4.00	0.08	**0.32**
			Q5.2	Emit high temperature waste heat from combustion equipment at a high point		5.00			
	L5	Reduce the amount of anthropogenic heat releases to the atmosphere	L5.1	Reduce the amount of anthropogenic heat releases to the atmosphere by preventing heat loss through outer walls and windows, as well as improving the energy efficiency of air-conditioning system		3.00	3.00	0.13	**0.39**
				a) Reduce cooling load of air-conditioning system by solar shading and improve the thermal insulation property of building	n/a air conditioning; assumed improved thermal insulation; total 4				
				b) Improve the efficiency of equipment systemsIntroduce energy-saving measures for air-conditioning ventilation, lighting and elevator systems	assumed energy saving lights; total 3				
				c) Utilize the natural energy #natural ventilation #daylight	total 5				
				d) Utilize the unused energy #exhaust heat from incineration plant #waste heat from sewage plant #seawater, river water and groundwater	no heat recovery device; total 0				
				e) Introduce high-performance infrastructuredistrict cooling and heating	n/a				
			L5.2	Reduce the temperature of exhaust air from building equipments	n/a	3.00			
			L5.3	Shift the peak of the anthropogenic heat released from the air-conditioning system by utilizing the heat storagingsystem, etc	n/a	3.00			
Total Q									**1.77**
Total L									**2.14**
BEE-HI							**19.125**	**71.5**	**0.26748252**

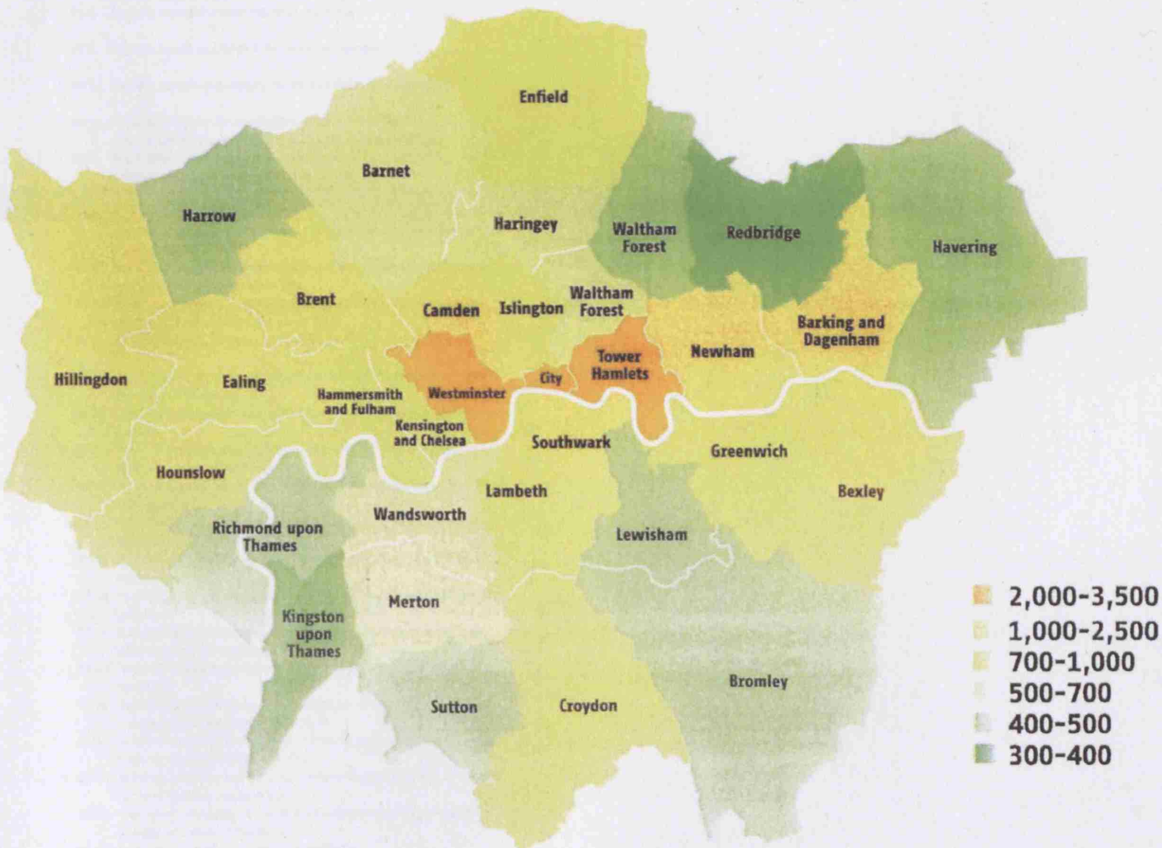
b. Dwelling B1

Categories					Summary design	Sub-Score	Score	weighting coefficients 200	TOTAL
1 Urban Ventilation									
	Q1	Improvethe thermal environment by ventilating the pedestrian space	Q1.1	Take wind condition into consideration in the building arrangement planning and building geometry design		4.00	4.00	0.37	**1.48**
			Q1.2	Create ventilation lanes by providing green spaces(Lawns, grassland, shrubs), but without objects such as tall trees that may block the pedestrian spaces frpm the wind flow		4.00			
	L1	Reduce the thermal effect on outside of the building siteby introducing airflows to the leeward	L1.1	Direct winds to leeward side through proper arrangement of buildings		4.00	3.33	0.24	**0.80**
			L1.2	Reduce the aspect ratio of buildings against prevailing wind direction in summer		2.00			
			L1.3	Direct winds to leeward of building using the height and geometry of building as well as buildings interval		4.00			
2 Shading									
	Q2	Improve the thermal environment in pedestrian space by shading	Q2.1	Create shades by trees, piloti, eaves and pergola in the pedestrian space			5.00	0.22	**1.10**
	L2	Reduce the thermal effect on outside of the building site by shading	L2.1	Make the shades by trees,piloti, eaves and pergolas in the building site			3.00	0.21	**0.63**
3 Ground surface covering materials									
	Q3	Improve the thermal environment in pedestrian space using green elements and water body	Q3.1	Reduce the ground surface temperature by providing green elements and water body		4.00	4.00	0.17	**0.68**
			Q3.2	Reduce asphalt-paved area within the building site		4.00			
	L3	Reduce the thermal effect on buildingon outside of the building site by appropriate ground cover materials	L3.1	Use ground cover materials with high permeability, high solar reflectance, etc.			3.00	0.20	**0.60**
4 Building materials									
	Q4	Improve the thermal environment in the pedestrian space by greening	Q4.1	Greening the exterior wall surface of building, particularly on the south andwest walls which receive high solar radiation		1.00	3.00	0.16	**0.48**
			Q4.2	Greening the rooftop that is accessible by people		5.00			
	L4	Reduce the thermal effect on outside of the building site by considering the thermal property of building materials	L4.1	Reduce heat flux into the building by greening the rooftop, or using high solar reflectance and low emittanceof long wave radiation roof covering materials		5.00	3.00	0.22	**0.66**
			L4.2	Reduce heat flux into the building by greening the exterior walls of building, or using high solar reflectance and low emittanceof long wave radiation wall covering materials		1.00			
5 Anthropogenic heat releases from building equipments									
	Q5	Improve the thermal environment in pedestrian space by considering the locations of anthropogenic heat released from building	Q5.1	Emit the anthropogenic heat from air-conditioning system at a higher point	n/a	5.00	5.00	0.08	**0.40**
			Q5.2	Emit high temperature waste heat from combustion equipment at a high point		5.00			
	L5	Reduce the amount of anthropogenic heat releases to the atmosphere	L5.1	Reduce the amount of anthropogenic heat releases to the atmosphere by preventing heat loss through outer walls and windows, as well as improving the energy efficiency of air-conditioning system		3.25	2.08	0.13	**0.27**
				a) Reduce cooling load of air-conditioning system by solar shading and improve the thermal insulation property of building	n/a air conditioning; assumed improved thermal insulation; total 4				
				b) Improve the efficiency of equipment systemsIntroduce energy-saving measures for air-conditioning ventilation, lighting and elevator systems	assumed energy saving lights; total 4				
				c) Utilize the natural energy #natural ventilation #daylight	total 5				
				d) Utilize the unused energy #exhaust heat from incineration plant #waste heat from sewage plant #seawater, river water and groundwater	no heat recovery device; total 0				
				e) Introduce high-performance infrastructuredistrict cooling and heating	n/a				
			L5.2	Reduce the temperature of exhaust air from building equipments	n/a	3.00			
			L5.3	Shift the peak of the anthropogenic heat released from the air-conditioning system by utilizing the heat storagingsystem, etc	n/a	0.00			
Total Q									**4.14**
Total L									**2.96**
BEE-HI							**78.5**	**50.9791667**	**1.53984471**

c. Office O1

Categories					Summary design	Sub-Score	Score	weighting coefficients 600	TOTAL
1 Urban Ventilation									
	Q1	Improvethe thermal environment by ventilating the pedestrian space	Q1.1	Take wind condition into consideration in the building arrangement planning and building geometry design		5.00	4.50	0.30	**1.35**
			Q1.2	Create ventilation lanes by providing green spaces(Lawns, grassland, shrubs), but without objects such as tall trees that may block the pedestrian spaces from the wind flow		4.00			
	L1	Reduce the thermal effect on outside of the building siteby introducing airflows to the leeward	L1.1	Direct winds to leeward side through proper arrangement of buildings		4.00	4.00	0.15	**0.60**
			L1.2	Reduce the aspect ratio of buildings against prevailing wind direction in summer		4.00			
			L1.3	Direct winds to leeward of building using the height and geometry of building as well as buildings interval		4.00			
2 Shading									
	Q2	Improve the thermal environment in pedestrian space by shading	Q2.1	Create shades by trees, piloti, eaves and pergola in the pedestrian space			5.00	0.20	**1.00**
	L2	Reduce the thermal effect on outside of the building site by shading	L2.1	Make the shades by trees,piloti, eaves and pergolas in the building site			4.00	0.15	**0.60**
3 Ground surface covering materials									
	Q3	Improve the thermal environment in pedestrian space using green elements and water body	Q3.1	Reduce the ground surface temperature by providing green elements and water body		4.00	2.50	0.15	**0.38**
			Q3.2	Reduce asphalt-paved area within the building site		1.00			
	L3	Reduce the thermal effect on buildingon outside of the building site by appropriate ground cover materials	L3.1	Use ground cover materials with high permeability, high solar reflectance, etc.			3.00	0.15	**0.45**
4 Building materials									
	Q4	Improve the thermal environment in the pedestrian space by greening	Q4.1	Greening the exterior wall surface of building, particularly on the south andwest walls which receive high solar radiation		0.00	0.00	0.15	**0.00**
			Q4.2	Greening the rooftop that is accessible by people		0.00			
	L4	Reduce the thermal effect on outside of the building site by considering the thermal property of building materials	L4.1	Reduce heat flux into the building by greening the rooftop, or using high solar reflectance and low emittanceof long wave radiation roof covering materials		4.00	3.00	0.15	**0.45**
			L4.2	Reduce heat flux into the building by greening the exterior walls of building, or using high solar reflectance and low emittanceof long wave radiation wall covering materials		2.00			
5 Anthropogenic heat releases from building equipments									
	Q5	Improve the thermal environment in pedestrian space by considering the locations of anthropogenic heat released from building	Q5.1	Emit the anthropogenic heat from air-conditioning system at a higher point		3.00	3.00	0.20	**0.60**
			Q5.2	Emit high temperature waste heat from combustion equipment at a high point		3.00			
	L5	Reduce the amount of anthropogenic heat releases to the atmosphere	L5.1	Reduce the amount of anthropogenic heat releases to the atmosphere by preventing heat loss through outer walls and windows, as well as improving the energy efficiency of air-conditioning system		3.00	2.00	0.40	**0.80**
				a) Reduce cooling load of air-conditioning system by solar shading and improve the thermal insulation property of building	total 4				
				b) Improve the efficiency of equipment systemsIntroduce energy-saving measures for air-conditioning ventilation, lighting and elevator systems	total 5				
				c) Utilize the natural energy #natural ventilation #daylight	total 2				
				d) Utilize the unused energy #exhaust heat from incineration plant #waste heat from sewage plant #seawater, river water and groundwater	heat recovery to ventilation system 4				
				e) Introduce high-performance infrastructuredistrict cooling and heating	total 0				
			L5.2	Reduce the temperature of exhaust air from building equipments	n/a	3.00			
			L5.3	Shift the peak of the anthropogenic heat released from the air-conditioning system by utilizing the heat storagingsystem, etc	n/a	0.00			
Total Q									**3.33**
Total L									**2.90**
BEE-HI							**58.125**	**52.5**	**1.10714286**

Appendix 10. Business emissions rate in London in tonnes per occupied 000 sq m (GVA Grimley, Property week, 2008)



Appendix 11. UHI ckecklist Score Sheet

a. Dwelling A1

Project Name (type)

Project address (surronding conditions & FR)

			Score	FR 1	TOTAL
1 Site & Layout			4	2.60	10.40
	SL 1	Wind: Reduce the ratio building height vs. street width	1		
	SL 2	Wind: Create ventilation lanes between building by introducing low level vegetation	1		
	SL 3	Wind: direct winds to leeward side using building height & geometry as well as interval	0		
	SL 4	Wind: reduce buildings aspect ratio against prevailing wind direction in summer	0		
	SL 5	External spaces: Introduce courtyard with vegetation and water feature	0		
	SL 6	External spaces: 50% of the site hard landscape covered with reflective surfaces (SRI > 29)	0		
	SL 7	External spaces: 50% of the site hard landscape covered with gravelled or permeable and porous paving	0		
	SL 8	External spaces: maximise green space area which should be arranged down a slope and re-use water run off	1		
	SL 9	External spaces: water features with minimal net water use and solar powered pumps to re-circulate water	0		
	SL 10	External spaces: vegetation species adapted to seasonal rainfalls (UKCIP)	0		
	SL 11	External spaces: maintenance strategy to include rainwater harvesting or grey-water recycling to irrigate gardens and	0		
	SL 12	External spaces: 50% of pedestrian space shaded by trees, piloti, eaves or pergola in summer	0		
	SL 13	External spaces: use deciduous planting	1		
2 External Building Envelop			1	1.00	1.00
	BE 1	Façade: 20% of cladding covered with reflective surfaces (SRI > 29)	0		
	BE 2	Façade: introduce vertical gardens, balconies with planters or climbers, particularly on the South and West elevations	0		
	BE 3	Façade: use light-weight cladding materials	0		
	BE 4	Façade: maximise North & South facing openings	1		
	BE 5	Façade: introduce shadding device and solar control glazing	0		
	BE 6	Façade: insulation & air tightness, 14% beyond Part M requirements for new building & 7% for existing building	0		
	BE 7	Roof: 50% of the roof covered with green roof or 75% with reflective surfaces or a combination of the two	0		
3 Building systems & Antropogenic heat			10	0.50	5.00
	BS 1	Ventilation: natural ventilation in combination with expose internal thermal mass	1		
	BS 2	Ventilation: use adaptive technique such as evaporative cooling to meet thermal comfort conditions	0		
	BS 3	Ventilation: increase floor to ceiling heights for natural ventilation or later addition of cooling mechanisms	1		
	BS 4	Air conditioning: consider low energy cooling techniques	1		
	BS 5	Air conditioning: reduce cooling load by solar shading and improve the thermal insulation	1		
	BS 6	Air conditioning: outlet to be located at a high point: above roof level	1		
	BS 7	Air conditioning: combine with heat-recovery system or generate electricity from wasted heat	1		
	BS 8	Air conditioning: powered by local renewable enegy source such as solar energy	1		
	BS 9	Air conditioning: shift the peak of the anthropogenic heat released by utilizing the heat storage system	1		
	BS 10	Building system & equipments: category A or as energy efficient as practicable	0		
	BS 11	Building system & equipments: use as much renewable energies as possible	0		
	BS 12	Building system & equipments: use control system such as timer, photo-sensor or centralised over-right	0		
	BS 13	Building system & equipments: monitor power consumed and hours run	0		
	BS 14	Building system & equipments: utilize unused energy such as the exhaust heat from incineration plant	0		
	BS 15	Building system & equipments: introduce high-performance district heating & cooling infrastructure	0		
	BS 16	Building system & equipments: reduce the temperature of exhaust air from building equipments	0		
	BS 17	Transport: encourage cycle and pedestrian travel by providing storage and shower facilities	1		
	BS 18	Transport: provide a green transport plan	1		
Surronding conditions					
	SC 1	Building site next to large open space, waterfront, park...			1.40
FINAL score					22.96

b. Dwelling B1

Project Name (type)

Project address (surrounding conditions & FR)

			Score	FR 1	TOTAL
1 Site & Layout			10	2.60	26.00
	SL 1	Wind: Reduce the ratio building height vs. street width	1		
	SL 2	Wind: Create ventilation lanes between building by introducing low level vegetation	1		
	SL 3	Wind: direct winds to leeward side using building height & geometry as well as interval	1		
	SL 4	Wind: reduce buildings aspect ratio against prevailing wind direction in summer	1		
	SL 5	External spaces: introduce courtyard with vegetation and water feature	0		
	SL 6	External spaces: 50% of the site hard landscape covered with reflective surfaces (SRI > 29)	1		
	SL 7	External spaces: 50% of the site hard landscape covered with gravelled or permeable and porous paving	1		
	SL 8	External spaces: maximise green space area which should be arranged down a slope and re-use water run off	1		
	SL 9	External spaces: water features with minimal net water use and solar powered pumps to re-circulate water	0		
	SL 10	External spaces: vegetation species adapted to seasonal rainfalls (UKCIP)	0		
	SL 11	External spaces: maintenance strategy to include rainwater harvesting or grey-water recycling to irrigate gardens and	1		
	SL 12	External spaces: 50% of pedestrian space shaded by trees, piloti, eaves or pergola in summer	1		
	SL 13	External spaces: use deciduous planting	1		
2 External Building Envelop			5	1.00	5.00
	BE 1	Façade: 20% of cladding covered with reflective surfaces (SRI > 29)	1		
	BE 2	Façade: introduce vertical gardens, balconies with planters or climbers, particularly on the South and West elevations	0		
	BE 3	Façade: use light-weight cladding materials	1		
	BE 4	Façade: maximise North & South facing openings	0		
	BE 5	Façade: introduce shadding device and solar control glazing	1		
	BE 6	Façade: insulation & air tightness, 14% beyond Part M requirements for new building & 7% for existing building	1		
	BE 7	Roof: 50% of the roof covered with green roof or 75% with reflective surfaces or a combination of the two	1		
3 Building Systems and antropogenic			12	0.50	6.00
	BS 1	Ventilation: natural ventilation in combination with expose internal thermal mass	1		
	BS 2	Ventilation: use adaptive technique such as evaporative cooling to meet thermal comfort conditions	0		
	BS 3	Ventilation: increase floor to ceiling heights for natural ventilation or later addition of cooling mechanisms	1		
	BS 4	Air conditioning: consider low energy cooling techniques	1		
	BS 5	Air conditioning: reduce cooling load by solar shading and improve the thermal insulation	1		
	BS 6	Air conditioning: outlet to be located at a high point: above roof level	1		
	BS 7	Air conditioning: combine with heat-recovery system or generate electricity from wasted heat;	1		
	BS 8	Air conditioning: powered by local renewable enegy source such as solar energy	1		
	BS 9	Air conditioning: shift the peak of the anthropogenic heat released by utilizing the heat storage system	1		
	BS 10	Building system & equipments: category A or as energy efficient as practicable	1		
	BS 11	Building system & equipments: use as much renewable energies as possible	0		
	BS 12	Building system & equipments: use control system such as timer, photo-sensor or centralised over-right	1		
	BS 13	Building system & equipments: monitor power consumed and hours run	0		
	BS 14	Building system & equipments: utilize unused energy such as the exhaust heat from incineration plant	0		
	BS 15	Building system & equipments: introduce high-performance district heating & cooling infrastructure	0		
	BS 16	Building system & equipments: reduce the temperature of exhaust air from building equipments	0		
	BS 17	Transport: encourage cycle and pedestrian travel by providing storage and shower facilities	1		
	BS 18	Transport: provide a green transport plan	1		
Surrounding conditions					
	SC 1	Building site next to large open space, waterfront, park...			1.40
FINAL score					51.80

c. Office O1

Project Name (type)

Project address (surronding conditions & FR)

			Score	FR 3	TOTAL
1 Site & Layout			**8**	**0.50**	**4.00**
	SL 1	Wind: Reduce the ratio building height vs. street width	0		
	SL 2	Wind: Create ventilation lanes between building by introducing low level vegetation	1		
	SL 3	Wind: direct winds to leeward side using building height & geometry as well as interval	0		
	SL 4	Wind: reduce buildings aspect ratio against prevailing wind direction in summer	0		
	SL 5	External spaces: Introduce courtyard with vegetation and water feature	1		
	SL 6	External spaces: 50% of the site hard landscape covered with reflective surfaces (SRI > 29)	1		
	SL 7	External spaces: 50% of the site hard landscape covered with gravelled or permeable and porous paving	1		
	SL 8	External spaces: maximise green space area which should be arranged down a slope and re-use water run off	1		
	SL 9	External spaces: water features with minimal net water use and solar powered pumps to re-circulate water	1		
	SL 10	External spaces: vegetation species adapted to seasonal rainfalls (UKCIP)	0		
	SL 11	External spaces: maintenance strategy to include rainwater harvesting or grey-water recycling to irrigate gardens and	0		
	SL 12	External spaces: 50% of pedestrian space shaded by trees, piloti, eaves or pergola in summer	1		
	SL 13	External spaces: use deciduous planting	1		
2 External Building Envelop			**3**	**1.00**	**3.00**
	BE 1	Façade: 20% of cladding covered with reflective surfaces (SRI > 29)	0		
	BE 2	Façade: introduce vertical gardens, balconies with planters or climbers, particularly on the South and West elevations	0		
	BE 3	Façade: use light-weight cladding materials	1		
	BE 4	Façade: maximise North & South facing openings	1		
	BE 5	Façade: introduce shadding device and solar control glazing	1		
	BE 6	Façade: insulation & air tightness, 14% beyond Part M requirements for new building & 7% for existing building	0		
	BE 7	Roof: 50% of the roof covered with green roof or 75% with reflective surfaces or a combination of the two	0		
3 Building systems & Antropogenic heat			**8**	**2.00**	**16.00**
	BS 1	Ventilation: natural ventilation in combination with expose internal thermal mass	0		
	BS 2	Ventilation: use adaptive technique such as evaporative cooling to meet thermal comfort conditions	0		
	BS 3	Ventilation: increase floor to ceiling heights for natural ventilation or later addition of cooling mechanisms	0		
	BS 4	Air conditioning: consider low energy cooling techniques	1		
	BS 5	Air conditioning: reduce cooling load by solar shading and improve the thermal insulation	1		
	BS 6	Air conditioning: outlet to be located at a high point: above roof level	0		
	BS 7	Air conditioning: combine with heat-recovery system or generate electricity from wasted heat;	1		
	BS 8	Air conditioning: powered by local renewable enegy source such as solar energy	0		
	BS 9	Air conditioning: shift the peak of the anthropogenic heat released by utilizing the heat storage system	0		
	BS 10	Building system & equipments: category A or as energy efficient as practicable	1		
	BS 11	Building system & equipments: use as much renewable energies as possible	0		
	BS 12	Building system & equipments: use control system such as timer, photo-sensor or centralised over-right	1		
	BS 13	Building system & equipments: monitor power consumed and hours run	1		
	BS 14	Building system & equipments: utilize unused energy such as the exhaust heat from incineration plant	0		
	BS 15	Building system & equipments: introduce high-performance district heating & cooling infrastructure	0		
	BS 16	Building system & equipments: reduce the temperature of exhaust air from building equipments	0		
	BS 17	Transport: encourage cycle and pedestrian travel by providing storage and shower facilities	1		
	BS 18	Transport: provide a green transport plan	1		
Surronding conditions					
	SC 2	Few open spaces around the building site			1.20
FINAL score					**27.60**